King County

Regional Hazard Mitigation Plan Update
Volume 1: Planning-Area-Wide Elements

July 2015

TETRA TECH

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19803 North Creek Parkway, Bothell, WA 98011
Tel 425. 877.2800 Fax 425. 877.2899 www.tetratech.com

King County

REGIONAL HAZARD MITIGATION PLAN UPDATE
VOLUME 1: PLANNING-AREA-WIDE ELEMENTS

JULY 2015

Prepared for:
King County
Office of Emergency Management
3511 NE 2nd Street
Renton, WA 98056

Prepared by:

TETRA TECH
complex world | CLEAR SOLUTIONS™

19803 North Creek Parkway, Bothell, WA 98011
Tel 425.877.2800 Fax 425.877.2899 www.tetratech.com

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ACKNOWLEDGMENTS

Project Manager

Janice Rahman
Emergency Management Program Manager
3511 NE 2nd St
Renton, WA 98056
(206) 205-4061
Janice.Rahman@Kingcounty.gov

Other King County Staff

Barnaby Dow

Nora Jagielo

Sam Ripley

Hong Nguyen

Consultants

Rob Flaner, CFM- Lead Project Planner, Tetra Tech, Inc.

Kristen Gelino, Junior Planner, Tetra Tech, Inc.

Carol Bauman, GIS/Hazus Risk Assessment Lead, Tetra Tech, Inc.

Ed Whitford, GIS Analyst, Tetra Tech, Inc.

Dan Portman, Technical Editor, Tetra Tech, Inc.

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EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

Hazard mitigation is the use of long-term and short-term policies, programs, projects, and other activities to alleviate the death, injury, and property damage that can result from a disaster. King County and a partnership of local governments within the County have developed and maintained a regional hazard mitigation plan to reduce risks from natural disasters. The plan complies with hazard mitigation planning requirements to maintain eligibility for funding under Federal Emergency Management Agency grant programs.

PREVIOUS HAZARD MITIGATION PLANNING IN KING COUNTY

Federal regulations require periodic updates of hazard mitigation plans to reevaluate recommendations, monitor the impacts of actions that have been accomplished, and determine if there is a need to change the focus of mitigation strategies. A jurisdiction covered by a plan that has expired is no longer in compliance with the federal requirements for hazard mitigation planning.

King County and a coalition of 39 planning partners prepared an initial hazard mitigation plan that was approved by the Federal Emergency Management Agency in November 2004. This document represents the second comprehensive update (the first update was made in 2009). The 2009 plan update process was truncated after back-to-back disasters in 2009—January flooding and March snowstorms—and the emergence of a significant flooding threat in the Green River Valley due to problems at Howard Hanson Dam. The truncated process resulted in a significant decrease in planning partners covered by the regional plan (12 local governments). Many of the original planning partners developed their own plans or let their plans expire. This 2014 update is a return to a truly regional planning effort. Fifty-four local governments are covered by this plan update, including King County, 26 city and town governments, and 27 special purpose districts, as listed in Tables ES-1 and ES-2.

The team that prepared the current update also prepared a five-year progress report of actions completed by all planning partners whose existing plan is replaced by this update. In the reporting period covered by the report, the partners started or completed 165 of 283 initiatives, 58 percent.

**TABLE ES-1.
MUNICIPAL PLANNING PARTNERS**

King County	City of Issaquah	City of Renton
City of Algona	City of Kent	City of SeaTac
City of Auburn	City of Kirkland	City of Shoreline
City of Bothell	City of Maple Valley	City of Snoqualmie
City of Burien	City of Medina	City of Tukwila
City of Carnation	City of Mercer Island	City of Woodinville
City of Clyde Hill	City of North Bend	Town of Beaux Arts Village
City of Duvall	City of Pacific	Town of Hunts Point
City of Federal Way	City of Redmond	Town of Skykomish

**TABLE ES-2.
SPECIAL PURPOSE DISTRICT PLANNING PARTNERS**

Coal Creek Utility District	Shoreline Fire
Covington Water District	Skyway Water & Sewer District
Highline Water District	Soos Creek Water & Sewer District
Kent Fire	Southwest Suburban Sewer District
Kent School District	Valley Regional Fire Authority
King County Fire District No. 2	Valley View Sewer District
King County Fire District No. 45	Vashon Island Fire & Rescue
King County Hospital District No. 2 (EvergreenHealth)	Water District 111
Midway Sewer District	Water District 125
North City Water District	Water District 19
Public Hospital District No. 1 (Valley Medical)	Water District 20
Riverview School District	Water District 90
Ronald Wastewater District	Woodinville Water District
Sammamish Plateau Water & Sewer District	

PLAN UPDATE PROCESS

Updating the plan consisted of the following phases:

- **Phase 1, Organize and Review**—A planning team was assembled for the plan update, consisting of staff from the King County Office of Emergency Management and a technical consultant. The team conducted outreach to establish the planning partnership. A 19-member steering committee was assembled to oversee the plan update, consisting of planning partner staff, citizens, and other stakeholders in the planning area. Coordination with other county, state and federal agencies involved in hazard mitigation occurred throughout the plan update process. This phase included a review of the existing plan, the Washington State Hazard Mitigation Plan, and existing programs that may support hazard mitigation actions.

Phase 2, Update the Risk Assessment—Risk assessment is the process of measuring the potential loss of life, personal injury, economic injury, and property damage resulting from natural hazards. This process assesses the vulnerability of people, buildings and infrastructure to natural hazards. Risk assessment models were enhanced with new data and technologies that have become available since 2009. The risk assessment included the following:

- Hazard identification and profiling
- Assessment of the impact of hazards on physical, social and economic assets
- Vulnerability identification
- Estimates of the cost of potential damage.

Planning partners used the risk assessment to rank risk and toh gauge the potential impacts of each hazard of concern on their jurisdiction. The mitigation actions recommended in this plan include some that address limitations in the modeling caused by insufficient data. For example, in light of the Oso landslide, King County has initiated an effort identified as an action item in this plan to better characterize landslide risks in the County.

- **Phase 3, Engage the Public**—The planning team implemented a publhic involvement strategy developed by the Steering Committee. The strategy included public meetings to present the risk assessment and the draft plan, a hazard mitigation survey, a County-sponsored website, and multiple media releases.
- **Phase 4, Assemble the Updated Plan**—The planning team and Steering Committee assembled a document to meet federal hazard mitigation planning requirements for all partners. The updated plan contains two volumes. Volume 1 contains components that apply to all partners and the broader planning area. Volume 2 contains all components that are jurisdiction-specific. Each planning partner has a dedicated annex in Volume 2.
- **Phase 5, Plan Adoption/Implementation**—Once pre-adoption approval has been granted by Washington State’s Emergency Management Division and FEMA Region X, the final adoption phase will begin. Each planning partner will individually adopt the updated plan. The plan maintenance process includes a schedule for monitoring and evaluating the plan’s progress periodically and producing a plan revision every 5 years. This plan maintenance strategy also includes processes for continuing public involvement and integration with other programs that can support or enhance hazard mitigation.

RISK ASSESSMENT RESULTS

Based on the risk assessment, hazards were ranked as follows for the risk they pose to the overall planning area:

1. Earthquake (High)
2. Severe Weather (High)
3. Severe Winter Weather (High)
4. Flood (Medium)
5. Landslide (Medium)
6. Wildfire (Medium)
7. Dam Failure (Low)
8. Avalanche (Low)
9. Volcano (Low)
10. Tsunami (Low).

Each planning partner also ranked hazards for its own area. Table ES-3 summarizes the categories of high, medium and low (relative to other rankings) based on the numerical ratings that each jurisdiction assigned each hazard. The results indicate the following general patterns:

- Earthquake, severe weather and severe winter weather generally ranked as the highest risks.
- Tsunami and avalanche were not ranked by most jurisdictions.
- Tsunami, volcano and wildfire tended to receive medium or low rankings based on the geographic location of each jurisdiction. Tsunami was ranked as a higher risk for coastal communities; wildfire was ranked higher for jurisdictions located farther from the highly developed areas near Puget Sound. Volcano was ranked higher for jurisdictions in the southwestern portion of the County near lahar hazard areas.
- Dam failure, volcano and wildland fire tended to have low ratings.

TABLE ES-3.
SUMMARY OF HAZARD RANKING RESULTS

	Number of Jurisdictions Assigning Ranking to Hazard			
	High	Medium	Low	Not Ranked
Avalanche	0	0	6	48
Dam Failure	1	8	20	25
Earthquake	49	5	0	0
Flood	10	25	17	2
Landslide	5	28	17	4
Severe Weather	40	13	1	0
Severe Winter Weather	44	9	1	0
Tsunami	0	3	11	40
Volcano	0	11	34	9
Wildland Fire	3	5	26	10

MITIGATION GUIDING PRINCIPLE, GOALS AND OBJECTIVES

The following principle guided the Steering Committee and the planning partnership in selecting the initiatives contained in this plan update:

> King County is a region that promotes community resilience by eliminating or reducing risks and adverse impacts from hazards, while encouraging hazard mitigation activities by all sectors.

The Steering Committee and the planning partnership established the following goals for the plan update:

1. Protect life and property.
2. Increase public awareness of hazards and mitigation opportunities.
3. Protect, restore and enhance environmental quality.
4. Leverage partnering opportunities.
5. Enhance planning activities.
6. Develop and implement cost-effective mitigation strategies.
7. Promote a sustainable economy.

The following objectives were identified that meet multiple goals, helping to establish priorities for recommended mitigation actions:

1. Increase the resilience of critical facilities, infrastructure and government operations to ensure continuity of operations during and after a hazard event.
2. Consider the impacts of hazards in all planning mechanisms that address current and future land uses and integrate hazard mitigation goals and objectives into other existing plans and programs within the planning area.

3. Develop, improve and protect systems that provide early warnings, emergency response communications and evacuation procedures.
4. Use the best available data, science and technologies to improve understanding and stakeholder awareness of the location and potential impacts of hazards, the vulnerability of building types and community development patterns, and the measures needed to mitigate hazards.
5. Seek feasible mitigation projects that provide the highest degree of hazard protection with the best benefit-cost ratio.
6. Emphasize the hazard mitigation message in and promote the value of public outreach and education programs, such as Take Winter By Storm and What to Do to Make it Through.
7. Improve coordination among all sectors to mitigate hazards.
8. Reduce hazard-related risks and vulnerability to potentially isolated populations within the planning area.
9. Retrofit, purchase or relocate structures in high hazard areas, including those known to be repetitively damaged.
10. Strengthen codes to improve the hazard resilience of new construction.
11. Leverage social networks and other social capital mechanisms to educate the public and stakeholders and promote resilience.
12. Seek actions that protect or improve the environment for future environmental conditions.
13. Form private/public partnerships to leverage and share resources.
14. Partner with the private sector, including small businesses, to promote hazard mitigation as part of standard business practice.
15. Educate businesses about contingency planning countywide, targeting small businesses and those located in high risk areas, and promote employee education about disaster preparedness while on the job and at home.

MITIGATION ACTIONS

Mitigation actions presented in this update are activities designed to reduce or eliminate losses resulting from natural hazards. The update process resulted in the identification of nearly 700 mitigation actions for implementation by individual planning partners, as presented in Volume 2 of this plan. In addition, the steering committee and planning partnership identified seven countywide initiatives benefiting the whole partnership, as listed in Table ES-4.

IMPLEMENTATION

Full implementation of the recommendations of this plan will require time and resources. The measure of the plan's success will be its ability to adapt to changing conditions. King County and its planning partners will assume responsibility for adopting the recommendations of this plan and committing resources toward implementation. The framework established by this plan commits all planning partners to pursue initiatives when the benefits of a project exceed its costs. The planning partnership developed this plan with extensive public input, and public support of the actions identified in this plan will help ensure the plan's success.

TABLE ES-4.
ACTION PLAN—COUNTYWIDE MITIGATION ACTIONS

Hazards Addressed	Lead Agency	Possible Funding Sources or Resources	Time Line[a]	Objectives
CW-1—Continue to participate in and support the "Resilient King County" initiative.				
All hazards	King County Office of Emergency Management (OEM)	Local, possible grant funding (FEMA, DHS)	Ongoing	1, 3, 4, 7, 13, 14, 15
CW-2—Continue to maintain a website that will house the regional hazard mitigation plan, its progress reports and all components of the plan's maintenance strategy to provide the planning partners and public ongoing access to the plan and its implementation.				
All Hazards	King County OEM	King County OEM operating budget	Ongoing	4, 6, 7, 11, 15
CW-3—Continue to leverage/support/enhance ongoing, regional public education and awareness programs (such as "Take Winter by Storm and "Make it Through") as a method to educate the public on risk, risk reduction and community resilience.				
All Hazards	King County and all planning partners	Local	Ongoing	4, 6, 7, 11, 13, 14, 15
CW-4—Continue to support the use, development and enhancement of a regional alert and notification system.				
All Hazards	King County OEM	Local, possible grant funding (FEMA, DHS, NWS, NOAA)	Ongoing	3, 4, 7, 13
CW-5—Strive to capture time-sensitive, perishable data—such as high water marks, extent and location of hazard, and loss information—following hazard events to support future updates to the risk assessment.				
All hazards	All Planning partners	Local, FEMA (PA)	Short-term	4, 7
CW-6—Encourage signatories for the regional coordination framework for disasters and planned events.				
All Hazards	King County OEM	Local	Ongoing	3, 7, 13, 14
CW-7—Continue ongoing communication and coordination in the implementation of the King County Regional Hazard Mitigation Plan and the 2013 King County Flood Hazard Management Plan.				
Flood	King County OEM, King County Department of Natural Resources & Parks, King County Flood Control District	Local	Ongoing	2, 4, 5, 7, 10, 12

PART 1— THE PLANNING PROCESS

CHAPTER 1.
INTRODUCTION TO THE PLANNING PROCESS

1.1 WHY PREPARE THIS PLAN?

1.1.1 The Big Picture

Hazard mitigation is defined as a way to reduce or alleviate the loss of life, personal injury, and property damage that can result from a disaster through long- and short-term strategies. It involves strategies such as planning, policy changes, programs, projects, and other activities that can mitigate the impacts of hazards. The responsibility for hazard mitigation lies with many, including private property owners; business and industry; and local, state, and federal government.

The federal Disaster Mitigation Act (DMA) of 2000 (Public Law 106-390) required state and local governments to develop hazard mitigation plans as a condition for federal disaster grant assistance. Prior to 2000, federal disaster funding focused on disaster relief and recovery, with limited funding for hazard mitigation planning. The DMA increased the emphasis on planning for disasters before they occur.

The DMA encourages state and local authorities to work together on pre-disaster planning, and it promotes sustainability for disaster resistance. “Sustainable hazard mitigation” includes the sound management of natural resources and the recognition that hazards and mitigation must be understood in the largest possible social and economic context. The enhanced planning network called for by the DMA helps local governments articulate accurate needs for mitigation, resulting in faster allocation of funding and more cost-effective risk reduction projects.

1.1.2 Local Concerns

Natural hazards impact citizens, property, the environment and the economy of King County. Avalanches, flooding, landslides, windstorms, severe winter storms, volcanoes, earthquakes and tsunamis have exposed King County residents and businesses to the financial and emotional costs of recovering after natural disasters. The risk associated with natural hazards increases as more people move to areas affected by those hazards.

The inevitability of natural hazards and the growing population and activity within King County create an urgent need to develop strategies, coordinate resources, and increase public awareness to reduce risk and prevent loss from future hazard events. Identifying risks posed by hazards and developing strategies to reduce the impact of a hazard event can assist in protecting life and property of citizens and communities. Local residents and businesses can work together with the County to create a hazard mitigation plan that addresses the potential impacts of hazard events. To accomplish these objectives, King County and a coalition of planning partners prepared a hazard mitigation plan in 2004. That initial plan was updated in 2009, and is now undergoing its second comprehensive update in accordance with federal requirements. Several factors initiated this planning effort:

- The King County area has significant exposure to numerous natural hazards that have caused millions of dollars in past damage.
- The participating partners wanted to be proactive in preparedness for the probable impacts of natural hazards.

- Local resources to undertake risk reduction initiatives are limited. Being able to leverage federal financial assistance is paramount to successful hazard mitigation.

With these factors in mind, King County is committed to maintaining this plan in accordance with federal requirements on behalf of the King County partnership that has committed to this process.

1.1.3 Purposes for Planning

This planning effort represents the second comprehensive update to the King County Regional Hazard Mitigation Plan since its initial development in 2004. This update identifies resources, information, and strategies for reducing risk from natural hazards. Elements and strategies in the plan were selected because they meet a program requirement and because they best meet the needs of the planning partners and their citizens. One of the benefits of multi-jurisdictional planning is the ability to pool resources and eliminate redundant activities within a planning area that has uniform risk exposure and vulnerabilities. The Federal Emergency Management Agency (FEMA) encourages multi-jurisdictional planning under its guidance for the DMA. The plan will help guide and coordinate mitigation activities throughout the planning area. The main purpose of this planning effort was to identify risks posed by hazards and to develop strategies to reduce the impact of hazard events on people and property in King County; however, the plan was also developed to meet the following objectives:

- Meet or exceed requirements of the DMA.
- Enable all planning partners to continue using federal grant funding to reduce risk through mitigation.
- Meet the needs of each planning partner as well as state and federal requirements.
- Create a risk assessment that focuses on King County hazards of concern.
- Create a single planning document that integrates all planning partners into a framework that supports partnerships within the county, and puts all partners on the same planning cycle for future updates.
- Meet the planning requirements of FEMA's Community Rating System (CRS), allowing planning partners that participate in the CRS program to maintain or enhance their CRS classifications.
- Coordinate existing plans and programs so that high-priority initiatives and projects to mitigate possible disaster impacts are funded and implemented.

1.2 WHO WILL BENEFIT FROM THIS PLAN?

All citizens and businesses of King County are the ultimate beneficiaries of this hazard mitigation plan update. The plan reduces risk for those who live in, work in, and visit the county. It provides a viable planning framework for all foreseeable natural hazards that may impact the county. Participation in development of the plan by key stakeholders in the county helped ensure that outcomes will be mutually beneficial. The resources and background information in the plan are applicable countywide, and the plan's goals and recommendations can lay groundwork for the development and implementation of local mitigation activities and partnerships.

1.3 HOW TO USE THIS PLAN

This plan has been set up in two volumes so that elements that are jurisdiction-specific can easily be distinguished from those that apply to the whole planning area:

- **Volume 1**—Volume 1 includes all federally required elements of a disaster mitigation plan that apply to the entire planning area. This includes the description of the planning process, public involvement strategy, goals and objectives, countywide hazard risk assessment, countywide mitigation actions, and a plan maintenance strategy. The following appendices provided at the end of Volume 1 include information or explanations to support the main content of the plan:
  - Appendix A—A glossary of acronyms and definitions
  - Appendix B—A 5-year progress report on actions identified in prior hazard plans
  - Appendix C—Planning partner bulletins
  - Appendix D—Hazard mitigation questionnaire and summary of results.
  - Appendix E—Concepts and methods used for hazard mapping
  - Appendix F—Plan adoption resolutions from Planning Partners
  - Appendix G—A template for progress reports to be completed as this plan is implemented.
- **Volume 2**—Volume 2 includes all federally required jurisdiction-specific elements, in annexes for each participating jurisdiction. It includes a description of the participation requirements established by the Steering Committee, as well as instructions and templates that the partners used to complete their annexes. Volume 2 also includes “linkage” procedures for eligible jurisdictions that did not participate in development of this plan but wish to adopt it in the future.

All planning partners will adopt Volume 1 in its entirety and at least the following parts of Volume 2: Part 1; each partner’s jurisdiction-specific annex; and the appendices.

CHAPTER 2.
PLAN UPDATE—WHAT HAS CHANGED

2.1 THE PREVIOUS PLANS

King County responded to DMA by developing the initial King County Regional Hazard Mitigation Plan in 2004. This multi-jurisdictional planning effort provided DMA compliance to 39 local governments (King County, 13 cities and 25 special purpose districts). The initial plan was formally approved by FEMA Region X on December 14, 2004. It identified and prioritized over 170 actions to be implemented by the planning partnership. This initial plan included two major sections:

- Common planning provisions—Completed by King County's Office of Emergency Management with input from individual participant agencies
- Jurisdiction annexes—Completed by each planning partner and including three parts:
  - Strategy
  - Jurisdiction annex administration
  - Initiatives/projects.

In 2009, the regional plan underwent its initial 5-year update in conformance with DMA requirements. The update process was intended to be conducted in two concurrent phases:

- Phase 1 was a King County base plan with a limited number of annexes for jurisdictions who were planning partners throughout the update process.
- Phase 2 was to incorporate the majority of remaining jurisdictions in the county.

A original planning schedule was shortened following back-to-back disasters in 2009—January flooding (federal disaster declaration DR-1817) and March snowstorms (federal disaster declaration DR-1825)—and the emergence of a significant flooding threat in the Green River Valley due to problems at Howard Hanson Dam. The planning team expedited Phase 1 to ensure King County's DMA compliance and ability to address the impacts of the disasters in unincorporated areas. This truncated process resulted in a significant decrease in planning partners covered by the regional plan. Many of the original partners developed their own plans or let their plans expire.

The 2009 Regional Plan, approved by FEMA Region X on January 28, 2010, provided DMA compliance for King County, four cities and seven special purpose districts. It maintained the basic format of the initial plan, with some revisions, including the addition of a dam safety risk assessment. The update identified and prioritized over 85 actions to be implemented by the participating partners.

2.2 WHY UPDATE?

Title 44 of the Code of Federal Regulations (44 CFR) stipulates that hazard mitigation plans must present a schedule for monitoring, evaluating, and updating the plan. This provides an opportunity to reevaluate recommendations, monitor the impacts of actions that have been accomplished, and determine if there is a need to change the focus of mitigation strategies. A jurisdiction covered by a plan that has expired is not able to pursue elements of federal funding under the Robert T. Stafford Act for which a current hazard mitigation plan is a prerequisite.

2.3 CHANGES IN DEVELOPMENT

Hazard mitigation plan updates must be revised to reflect changes in development within the planning area during the previous performance period of the plan (44 CFR Section 201.6(d)(3)). The plan must describe changes in development in hazard-prone areas that increased or decreased vulnerability for each jurisdiction since the last plan was approved. If no changes in development impacted the jurisdiction's overall vulnerability, plan updates may validate the information in the previously approved plan. The intent of this requirement is to ensure that the mitigation strategy continues to address the risk and vulnerability of existing and potential development and takes into consideration possible future conditions that could impact vulnerability.

The King County planning area experienced a 14.6-percent increase in population between 2000 and 2013, an average annual growth rate of 1.06 percent per year. The County and its cities have adopted comprehensive plans that govern land-use decisions and policy-making in their jurisdictions as well as building codes and specialty ordinances based on state and federal mandates. This plan update assumes that some new development triggered by the increase in population occurred in hazard areas. Because all such new development would have been regulated pursuant to local programs and codes, it is assumed that vulnerability did not increase even if exposure did. This is validated by the fact that no hazard events in the planning area during the performance period caused significant losses.

The risk assessment for the initial King County regional plan was more subjective than the assessment for this update, as it used qualitative analyses and assumptions while the updated plan used a more quantitative approach. Given this difference, it is not possible to compare the results of the two assessments to see if risk has increased. Now that the planning area is equipped with a Hazus model, this type of comparative analysis will be possible for future updates to this plan.

2.4 THE 5-YEAR PROGRESS REPORT

The 2009 plan update included a plan maintenance protocol that called for annual review and updates to the plan, with a goal of facilitating linkage to the 2009 update by all the original planning partners. This did not occur during the performance period, primarily because many of the original planning partners developed their own plans to comply with the DMA.

Prior to preparing the current update with its expanded list of partners, many of whom had their own plans that this plan update will replace, the planning team prepared a five-year progress report of actions completed by all planning partners whose existing plan is replaced by this update. The progress report used the template for annual progress reporting that is described in Chapter 21. of this plan. This allowed planning partners to become familiar with the proposed process of annual progress reporting.

The five-year progress report is included in Appendix B of this volume. The reporting period for this report was 2010 through 2014. The report was completed by 24 local governments with prior plan coverage. It reports on the status of 283 initiatives. Upon completion of this report, it will be posted on the hazard mitigation plan website as the placeholder for all future progress reports completed from here on out.

2.5 THE UPDATED PLAN—WHAT IS DIFFERENT?

The King County Office of Emergency Management used the current update process to make significant changes to the format and content of the regional plan. The plan was re-packaged to better support a larger partnership and to establish a plan maintenance and implementation protocol that clearly defines the King County Office of Emergency Management's commitment to the plan's ongoing success:

- The planning partnership was increased to 53 planning partners.
- The plan was developed in two volumes. Volume 1 contains all required elements that apply to the entire planning area; Volume 2 contains elements that are jurisdiction-specific.
- A comprehensive risk assessment is included for 10 hazards of concern, and an overview is provided for other hazards of interest.
- The risk assessments made robust use of FEMA's Hazus-MH risk assessment software.
- A risk-ranking methodology was implemented that quantifies the impacts of each hazard so that they can be compared to one another.
- A new methodology was implemented for the prioritization of actions.
- A plan maintenance strategy is presented that includes a protocol and tools to support annual progress reporting, as well as a protocol for grant coordination.
- A prescribed linkage procedure will allow for future expansion of the partnership outside of the 5-year update window.
- A suite of tools and templates is provided to promote consistency of all future updates to the plan

These changes set a course to re-engage as many of the original planning partners as possible and to increase the coverage of the plan. This update represents a complete revision of the previous versions of the King County Regional Plan. Its content is different and the process used to develop it was different. The update process was conducted as if this were an initial planning effort. This approach accommodated the many planning partners who had not previously been covered by a hazard mitigation plan. Table 2 -5 indicates the major changes between the two plans as they relate to 44 CFR planning requirements.

**TABLE 2-5.
PLAN CHANGES CROSSWALK**

44 CFR Requirement	2009 Plan update	Updated Plan
§201.6(b): In order to develop a more comprehensive approach to reducing the effects of natural disasters, the planning process shall include: (1) An opportunity for the public to comment on the plan during the drafting stage and prior to plan approval; (2) An opportunity for neighboring communities, local and regional agencies involved in hazard mitigation activities, and agencies that have the authority to regulate development, as well as businesses, academia and other private and non-profit interests to be involved in the planning process; and (3) Review and incorporation, if appropriate, of existing plans, studies, reports, and technical information.	The 2009 plan update was conducted through a Regional Hazard Mitigation Planning Team made up predominantly of County staff. Due to the need to expedite the process, many of the outreach techniques used in the 2004 plan were not used in this update. A website was established, press releases were disseminated and 14 public meetings were held to disclose the plan update process. Agency coordination included Washington Emergency Management Division and FEMA Region X. The response to the Howard Hanson Dam crisis provided numerous opportunities to discuss the plan update process.	The Plan update was facilitated through a Steering Committee made up of stakeholders within the planning area. The Steering Committee was responsible for : defining planning partner expectations, review of relevant plans and programs, agency coordination, identification of a vision, goals and objectives, confirmation of a public involvement strategy, development of a plan maintenance strategy and review and approval of the draft plan.
§201.6(c)(2): The plan shall include a risk assessment that provides the factual basis for activities proposed in the strategy to reduce losses from identified hazards. Local risk assessments must provide sufficient information to enable the jurisdiction to identify and prioritize appropriate mitigation actions to reduce losses from identified hazards.	The plan update used an existing Hazard Identification and Vulnerability Assessment as the basis for the risk assessment. This followed the format and content of the 2004 plan. The Hazard Identification and Vulnerability Assessment profiled eight natural hazards (avalanche, drought, earthquake, flood, landslide, tsunami, dam safety and) and four non-natural hazards (hazardous materials, terrorism, civil disorder and cyber-terrorism).	Part 2 of Volume 1 presents a comprehensive risk assessment for the planning area that looks at 10 natural hazards of concern: avalanche, dam failure, earthquake, flood, landslide, severe weather, severe winter weather, tsunami, volcano, wildfire, and provides a profile of other hazards of interest (non-natural hazards). This assessment used the best available data and science together with the Hazus-MH (version 2.2) risk assessment software.

TABLE 2-5.
PLAN CHANGES CROSSWALK

44 CFR Requirement	2009 Plan update	Updated Plan
§201.6(c)(2)(i): [The risk assessment shall include a] description of the … location and extent of all natural hazards that can affect the jurisdiction. The plan shall include information on previous occurrences of hazard events and on the probability of future hazard events.	A profile was provided including maps that illustrate the extent and location of each identified hazard of concern. These profiles included information on previous occurrences of hazard events and on the probability of future hazard events.	Comprehensive risk assessments of each hazard of concern are presented in Volume 1 Chapter 8. through Chapter 17.. Each chapter includes the following: • Hazard profile, including maps of extent and location, historical occurrences, frequency, severity and warning time. • Secondary hazards • Exposure of people, property, critical facilities and environment. • Vulnerability of people, property, critical facilities and environment. • Future trends in development • Scenarios • Issues Each hazard is compared to each other via a risk ranking methodology in Chapter 19..
§201.6(c)(2)(ii): [The risk assessment shall include a] description of the jurisdiction's vulnerability to the hazards described in paragraph (c)(2)(i). This description shall include an overall summary of each hazard and its impact on the community	Vulnerability was described for each hazard of concern in a subjective context. A Level-1 hazard analysis for earthquake and flood hazards summarized losses to general building stock, critical facilities and estimated casualties. Each profile included a discussion on impacts and past mitigation efforts.	Vulnerability was assessed for all hazards of concern. The Hazus-MH computer model was used for the dam failure, earthquake, flood and tsunami hazards. These were Level-2 (user-defined) analyses using planning partner and County data. Critical facilities were defined and inventoried using the Hazus Comprehensive Data Management System. Hazus outputs were generated for other hazards by applying an estimated damage function to affected assets. The asset inventory was extracted from the Hazus-MH model. Best available data was used for all analyses. Outputs were generated for each participating planning partner.
§201.6(c)(2)(ii): [The risk assessment] must also address National Flood Insurance Program insured structures that have been repetitively damaged floods	The plan describes the National Flood Insurance Program and the participation status of participating communities. This is contained in the flood hazard profile.	The repetitive loss section was enhanced to meet new DMA and CRS planning requirements. The update includes a comprehensive analysis of repetitive loss areas that includes an inventory of the number and types of structures in the repetitive loss area. Repetitive loss areas were delineated, causes of repetitive flooding was cited, and these areas were reflected on maps. National Flood Insurance Program capability is assessed in the jurisdictional annexes for each municipal planning partner.

**TABLE 2-5.
PLAN CHANGES CROSSWALK**

44 CFR Requirement	2009 Plan update	Updated Plan
§201.6(c)(2)(ii)(A): The plan should describe vulnerability in terms of the types and numbers of existing and future buildings, infrastructure, and critical facilities located in the identified hazard area.	A detailed vulnerability analysis that includes building counts and loss estimates was provided for the flood hazard. This level of detail was not provided for the other hazards of concern.	A complete inventory of the numbers and types of buildings exposed was generated for each hazard of concern. The Steering Committee defined "critical facilities" as they pertained to the planning area, and these facilities were inventoried by exposure. Each hazard chapter provides a discussion of future development trends as they pertain to the hazard.
§201.6(c)(2)(ii)(B): [The plan should describe vulnerability in terms of an] estimate of the potential dollar losses to vulnerable structures identified in paragraph (c)(2)(i)(A) and a description of the methodology used to prepare the estimate.	This level of detail was provided only for the flood hazard.	Dollar loss estimations were generated for all hazards of concern. These were generated by Hazus for the dam failure, earthquake, flood and tsunami hazards. For the other hazards, loss estimates were generated by applying a regionally relevant damage function to the exposed inventory. In all cases, a damage function was applied to an asset inventory. The asset inventory was the same for all hazards and was generated in the Hazus-MH model.
§201.6(c)(2)(ii)(C): [The plan should describe vulnerability in terms of] providing a general description of land uses and development trends within the community so that mitigation options can be considered in future land use decisions.	The plan includes an overall description of land use with in the planning area, but does not detail that discussion by hazard. The plan includes no discussion on future land use or development trends.	There is a discussion on future development trends as they pertain to each hazard of concern. This discussion looks predominantly at the existing land use and the current regulatory environment that dictates this land use.
§201.6(c)(2)(iii): For multi-jurisdictional plans, the risk assessment must assess each jurisdiction's risks where they vary from the risks facing the entire planning area.	Risk assessment results were reported on a countywide scale and not broken out by municipality.	Risk assessment results were generated for each planning partner to support the concept of risk ranking, which was performed by each planning partner. Risk ranking was used by each planning partner to provide vision and focus to action plan development.
§201.6(c)(3): The plan shall include a mitigation strategy that provides the jurisdiction's blueprint for reducing the potential losses identified in the risk assessment, based on existing authorities, policies, programs and resources, and its ability to expand on and improve these existing tools.	The 2009 update carried over the same action plan protocol deployed by the 2004 plan. This included a process for prioritization of mitigation actions.	Action plans were developed for each planning partner via a facilitated process that includes: • Risk ranking • Capability assessment • Action alternative review • Action selection • Action prioritization • Action category analysis

TABLE 2-5.
PLAN CHANGES CROSSWALK

44 CFR Requirement	2009 Plan update	Updated Plan
§201.6(c)(3)(i): [The hazard mitigation strategy shall include a] description of mitigation goals to reduce or avoid long-term vulnerabilities to the identified hazards.	The 2009 update carried over the mission statement, vision, 6 goals and 21 objectives from the 2004 vision statement. The objectives were listed as subsets of the goals.	The plan update identifies a guiding principle, 7 goals and 15 objectives. Goals were selected that support the guiding principle, objectives were selected that meet multiple goals, and actions were selected and prioritized based on meeting multiple objectives.
§201.6(c)(3)(ii): [The mitigation strategy shall include a] section that identifies and analyzes a comprehensive range of specific mitigation actions and projects being considered to reduce the effects of each hazard, with particular emphasis on new and existing buildings and infrastructure.	The 2009 plan does not categorize mitigation alternatives. However, based on a review of the update, the actions identified cover the six categories of mitigation (prevention, property protection, public education , natural resource protection, emergency services and capital projects.)	A hazard mitigation catalog was developed through a facilitated process that looks at strengths, weaknesses, obstacles and opportunities in the planning area. This catalog identifies actions that manipulate the hazard, reduce exposure to the hazard, reduce vulnerability, and increase mitigation capability. The catalog further segregates actions by scale of implementation. A table in the action plan section analyzes each action by mitigation type to illustrate the range of actions selected.
§201.6(c)(3)(ii): [The mitigation strategy] must also address the jurisdiction's participation in the National Flood Insurance Program, and continued compliance with the program's requirements, as appropriate.	A brief discussion on the National Flood Insurance Program is provided in the flood hazard profile. There is no jurisdiction-specific discussion on National Flood Insurance Program capability.	All municipal planning partners were asked to assess National Flood Insurance Program capability in their jurisdictional annexes. All participating communities have identified actions supporting continued compliance and good standing under the program.
§201.6(c)(3)(iii): [The mitigation strategy shall describe] how the actions identified in section (c)(3)(ii) will be prioritized, implemented, and administered by the local jurisdiction. Prioritization shall include a special emphasis on the extent to which benefits are maximized according to a cost benefit review of the proposed projects and their associated costs.	All actions identified are prioritized and there is discussion on benefits and costs of each project. However, there is no direct correlation to the benefit-cost review and action prioritization specified in the plan.	Each of the recommended initiatives is prioritized using a qualitative methodology that looked at the objectives the project will meet, the timeline for completion, how the project will be funded, the impact of the project, the benefits of the project and the costs of the project. This prioritization scheme is detailed in Chapter 21..
§201.6(c)(4)(i): [The plan maintenance process shall include a] section describing the method and schedule of monitoring, evaluating, and updating the mitigation plan within a five-year cycle.	Section 2 of the plan identifies a plan maintenance protocol that includes an approach for continuing public involvement and annual review.	A detailed plan maintenance strategy is provided that includes the following: • Annual review and progress reporting • Defined role for Steering Committee • Plan update triggers • Plan incorporation guidelines • Strategy for continuing public involvement • Grant coordination protocol

**TABLE 2-5.
PLAN CHANGES CROSSWALK**

44 CFR Requirement	2009 Plan update	Updated Plan
§201.6(c)(4)(ii): [The plan shall include a] process by which local governments incorporate the requirements of the mitigation plan into other planning mechanisms such as comprehensive or capital improvement plans, when appropriate.	The plan did not include this discussion	This is included in the detailed plan maintenance strategy in Chapter 21..
§201.6(c)(4)(iii): [The plan maintenance process shall include a] discussion on how the community will continue public participation in the plan maintenance process.	Section 2 of the plan includes detailed discussion on continuing public involvement,	This is included in the detailed plan maintenance strategy in Chapter 21.
§201.6(c)(5): [The local hazard mitigation plan shall include] documentation that the plan has been formally adopted by the governing body of the jurisdiction requesting approval of the plan (e.g., City Council, County Commission, Tribal Council).	The plan includes discussion on plan implementation which includes plan adoption	53 planning partners will seek DMA compliance for this plan. Appendix F contains the resolutions of all planning partners that adopted this plan

CHAPTER 3.
PLAN METHODOLOGY

To develop the King County Regional Hazard Mitigation Plan Update, the County followed a process that had the following primary objectives:

- Secure grant funding
- Form a planning team
- Establish a planning partnership
- Define the planning area
- Establish a steering committee
- Coordinate with other agencies
- Review existing programs
- Engage the public.

3.1 GRANT FUNDING

This planning effort was supplemented by a grant from FEMA. The King County Office of Emergency Management was the applicant agent for the grant. The grant was applied for in 2010 and funding was appropriated in 2011. It covered 75 percent of the cost for development of this plan; the County and its planning partners covered the balance through in-kind contributions.

3.2 FORMATION OF THE PLANNING TEAM

King County hired Tetra Tech, Inc. to assist with development and implementation of the plan. The Tetra Tech project manager assumed the role of the lead planner, reporting directly to a County-designated project manager. A planning team was formed to lead the planning effort, made up of the following members:

- Janice Rahman, King County Office of Emergency Management Project Manager
- Sam Ripley, King County Office of Emergency Management Project Coordinator
- Nora Jagielo, King County Office of Emergency Management Project Coordinator
- Rob Flaner, Tetra Tech, Project Manager/Lead Project Planner
- Kristen Gelino, Tetra Tech, Junior Planner
- Carol Bauman, Tetra Tech, Senior GIS Analyst and Risk Assessment Lead
- Dan Portman, Tetra Tech, Technical Editor.

3.3 ESTABLISHMENT OF THE PLANNING PARTNERSHIP

It was important to King County that this update re-engage the original planning partnership from the 2004 plan and be open to all eligible local governments. The planning team made a presentation at a stakeholder meeting on January 24, 2013 to introduce the mitigation planning process to all eligible local governments and solicit planning partners. Key meeting objectives were as follows:

- Provide an overview of the Disaster Mitigation Act.
- Describe the reasons for a plan.
- Outline the County work plan.
- Outline planning partner expectations.
- Seek commitment to the planning partnership.
- Seek volunteers for the Steering Committee.
- Explain the role of the King County Office of Emergency Management in maintaining the plan and the partnership.

Each jurisdiction wishing to join the planning partnership was asked to provide a “letter of intent to participate” that designated a point of contact for the jurisdiction and confirmed the jurisdiction’s commitment to the process and understanding of expectations. Linkage procedures have been established (see Volume 2 of this plan) for any jurisdiction wishing to link to the King County plan in the future. The municipal planning partners covered under this plan are shown in Table 3 -6. The special purpose district planning partners are shown in Table 3 -7.

To keep the partners engaged through the 14-month planning process, the planning team issued periodic bulletins apprising the partners of plan development milestones. Five bulletins were disseminated to all planning partners during this process. These bulletins are presented in Appendix C of this volume.

TABLE 3-6.
MUNICIPAL PLANNING PARTNERS

Jurisdiction	Point of Contact	Jurisdiction	Point of Contact
King County	Janice Rahman	City of Mercer Island	Jennifer Franklin
City of Algona	Chief Lee Gaskill	City of North Bend	Mark Rigos
City of Auburn	Sarah Miller	City of Pacific	Chief John Calkins
City of Bothell	Jennifer Warmke	City of Redmond	Debbie Newman
City of Burien	Nhan Nguyen	City of Renton	Deborah Needham
City of Carnation	Ken Carter	City of SeaTac	Patrick Lowery
City of Clyde Hill	Mitch Wasserman	City of Shoreline	Gail Harris
City of Duvall	Boyd Benson	City of Snoqualmie	Lauren Hollenbeck
City of Federal Way	Ray Gross	City of Tukwila	Marty Grisham
City of Issaquah	Bret Heath	City of Woodinville	Alexandra Sheeks
City of Kent	Kimberly Behmyer	Town of Beaux Arts Village	Sue Ann Spens
City of Kirkland	Pattijean Hooper	Town of Hunts Point	Sue Ann Spens
City of Maple Valley	Jeff Johnson	Town of Skykomish	Deborah Allegri
City of Medina	Kris Finnigan		

**TABLE 3-7.
SPECIAL PURPOSE DISTRICT PLANNING PARTNERS**

Jurisdiction	Point of Contact	Jurisdiction	Point of Contact
Fire Districts		**Water & Sewer Districts**	
Fire District No. 2	Lt. Milton Guerreiro	Coal Creek Utility District	Robert Russell
Fire District No. 45	D/C Joel Kuhnhenn	Covington Water District	Robert Taylor
Kent Fire	Kimberly Behymer	Highline Water District	Mike Becker
Shoreline Fire	B/C Steve Taylor	North City Water District	Diane Pottinger
Valley Regional Fire Authority	D/C Mike Gerber	Midway Sewer District	Tim Campbell
Vashon Island Fire & Rescue	Chief Hank Lipe	Ronald Wastewater District	George Dicks
		Sammamish Plateau Water & Sewer District	Janet Sailer
Hospital Districts		Skyway Water & Sewer District	Cynthia Lamothe
King County Hospital District No. 2 (EvergreenHealth)	Barb Jensen	Soos Creek Water & Sewer District	Pamela Cobley
Public Hospital District No. 1 (Valley Medical)	Jim Tritten	Southwest Suburban Sewer District	Laura Gallez
School Districts		Valley View Sewer District	Dana Dick
Kent School District	Beth Gilbertson	Water District 19	Jeffrey Lakin
Riverview School District	William Adamo	Water District 20	Dick Swabb
		Water District 90	Tom Hoffman
		Water District 111	Pamela Cobley
		Water District 125	Mark Parsons
		Woodinville Water District	Kurt Oakland

3.4 DEFINING THE PLANNING AREA

The planning area was defined as all incorporated and unincorporated areas of King County as well as the incorporated areas of cities that cross County boundaries: Auburn, Bothell, Milton and Pacific. All partners to this plan have jurisdictional authority within this planning area.

3.5 THE STEERING COMMITTEE

Hazard mitigation planning enhances collaboration and support among diverse parties whose interests can be affected by hazard losses. A steering committee was formed to oversee all phases of the plan. The members of this committee included key planning partner staff, citizens, and other stakeholders from within the planning area. The planning team assembled a list of candidates representing interests within the planning area that could have recommendations for the plan or be impacted by its recommendations. The partnership confirmed a committee of 19 members at the kickoff meeting. Table 3 -8 lists the committee members.

**TABLE 3-8.
STEERING COMMITTEE MEMBERS**

Name	Title/Jurisdiction or Agency
Janice Rahman (Chair)	Emergency Management Program Manager/King County Office of Emergency Management
Rick Wallace (Vice Chair)	President/Vashon Be Prepared (Citizen)
Barnaby Dow	Emergency Management Program Manager/King County Office of Emergency Management
Bob Freitag	Director of the Institute for Hazard Mitigation Planning and Research/University of Washington
Denis Uhler	Director of Supply Chain Management/Overlake Hospital
Dominic Maranzo	Emergency Manager/City of Kent
Ed Reed	Zone 3 Coordinator/King County
Gail Harris	Emergency Manager/City of Shoreline
James Kraman	Event Manager/Century Link Field
James Tritten	Emergency Preparedness Manager /Valley Medical Center
Kimberly Behymer	Program Coordinator/City of Kent
Lee Gaskill	Police Lieutenant/City of Algona
Mark Chubb	Fire Chief/King County Fire District No. 20
Mike Ryan	Zone 1 Coordinator/King County
Milton Guerreiro	Fire Lieutenant/King County Fire District No. 2 – Burien Fire
Monica Walker	Project/Program Manager/King County Water and Land Resources Division
Robert Taylor	Water Resources Manager/Covington Water District
Sarah Miller	Emergency Preparedness Manager/City of Auburn
Scott Emry	Risk Management Manager/Lake Washington School District

Leadership roles and ground rules were established during the Steering Committee's initial meeting on February 20, 2013. The Steering Committee agreed to meet monthly as needed throughout the course of the plan's development. The planning team facilitated each Steering Committee meeting, which addressed a set of objectives based on the work plan established for the plan. The Steering Committee met 10 times from February 2013 through March 2014. Meeting agendas, notes and attendance logs are available for review upon request. All Steering Committee meetings were open to the public, and agendas and meeting notes were posted to the hazard mitigation plan website.

3.6 COORDINATION WITH OTHER AGENCIES

Opportunities for involvement in the planning process must be provided to neighboring communities, local and regional agencies involved in hazard mitigation, agencies with authority to regulate development, businesses, academia, and other private and nonprofit interests (44 CFR, Section 201.6(b)(2)). This task was accomplished by the planning team as follows:

- **Steering Committee Involvement**—Agency representatives were invited to participate on the Steering Committee.

- **Agency Notification**—The following agencies were invited to participate in the plan development from the beginning and were kept apprised of plan development milestones:
  - Washington Emergency Management Division
  - Washington Department of Ecology
  - Washington Department of Natural Resources
  - FEMA Region X
  - Snohomish County
  - Pierce County
  - Muckleshoot Tribe.

  These agencies received notices that included meeting announcements, meeting agendas, meeting minutes and bulletins by e-mail throughout the plan development process. These agencies supported the effort by attending meetings or providing feedback on issues.
- **Pre-Adoption Review**—All the agencies listed above were provided an opportunity to review and comment on this plan, primarily through the hazard mitigation plan website (see Section 3.8). Each agency was sent an e-mail message informing them that draft portions of the plan were available for review. In addition, the complete draft plan was sent to FEMA's Community Rating System contractor, the Insurance Services Office, Inc. (ISO), for a pre-adoption review to ensure CRS program compliance.

3.7 REVIEW OF EXISTING PROGRAMS

Hazard mitigation planning must include review and incorporation, if appropriate, of existing plans, studies, reports and technical information (44 CFR, Section 201.6(b)(3)). Chapter 6. of this plan provides a review of laws and ordinances in effect within the planning area that can affect hazard mitigation actions. In addition, the following programs can affect mitigation within the planning area:

- 2006 King County Flood Hazard Management Plan
- 2013 King County Flood Hazard Management Plan Update and Progress Report and Amendment to the 2006 Flood Hazard Mitigation Plan for the Community Rating System
- 2010 King County Flood Control District Hazard Mitigation Plan
- 2010 King County Strategic Plan
- The "Resilient King County" Initiative
- 2012 King County Comprehensive Plan
- The King County Shoreline Master Program
- 2007 King County Buildable Lands report
- King County Critical Areas Ordinance (Title 21.A.24)
- King County Strategic Climate Action Plan

An assessment of all planning partners' regulatory, technical and financial capabilities to implement hazard mitigation actions is presented in Chapter 21. and in the individual jurisdiction-specific annexes in Volume 2. Many of these relevant plans, studies and regulations are cited in the capability assessment.

3.8 PUBLIC INVOLVEMENT

Broad public participation in the planning process helps ensure that diverse points of view about the planning area's needs are considered and addressed. The public must have opportunities to comment on disaster mitigation plans during the drafting stages and prior to plan approval (44 CFR, Section 201.6(b)(1)). The Community Rating System expands on these requirements by making CRS credits available for optional public involvement activities.

3.8.1 Strategy

The strategy for involving the public in this plan emphasized the following elements:

- Include members of the public and other non-governmental stakeholders on the Steering Committee.
- Use a questionnaire to determine if the public's perception of risk and support of hazard mitigation has changed since the initial planning process.
- Attempt to reach as many planning area citizens as possible using multiple media.
- Identify and involve planning area stakeholders.

Stakeholders and the Steering Committee

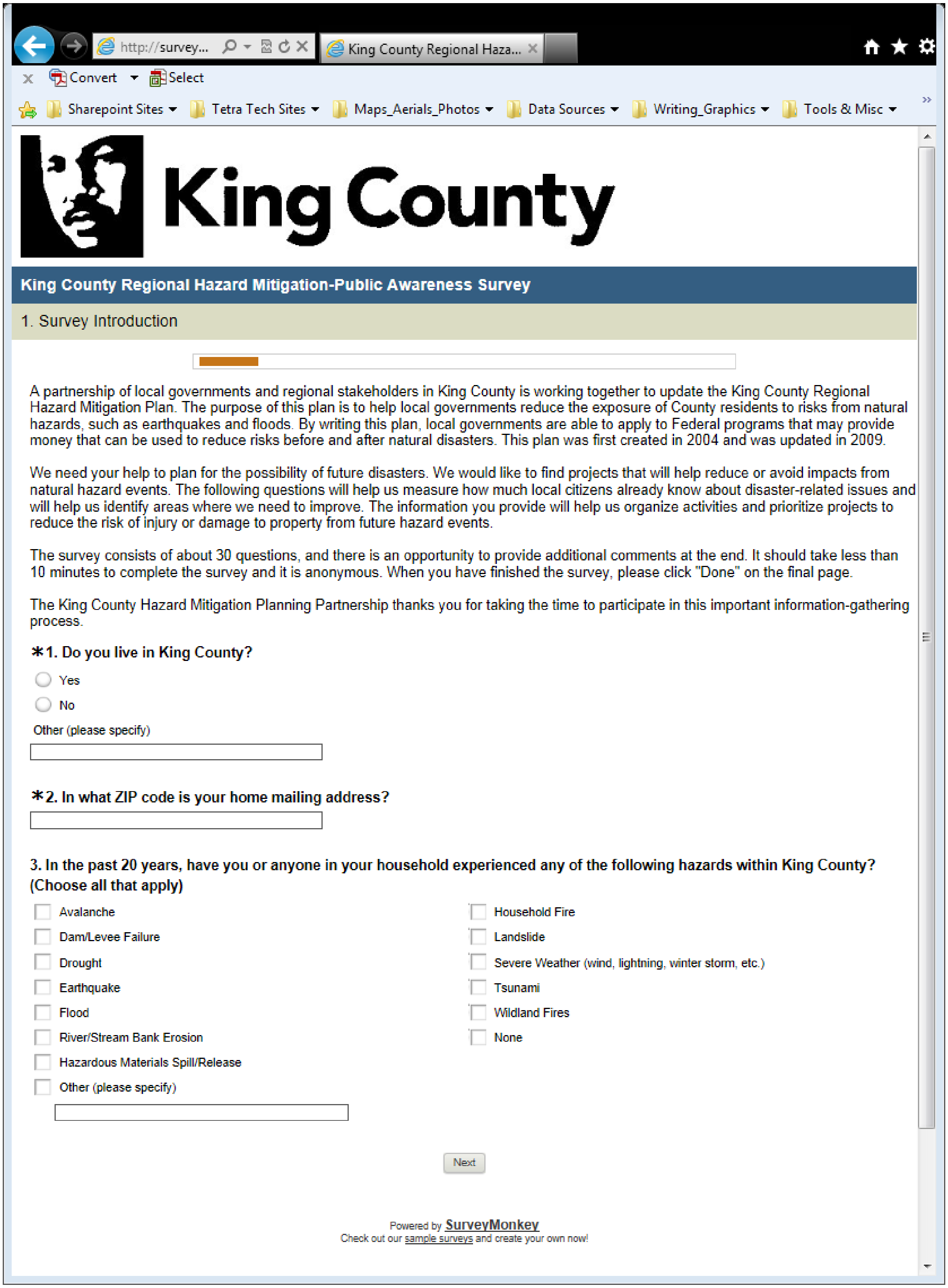
Stakeholders are the individuals, agencies and jurisdictions that have a vested interest in the recommendations of the hazard mitigation plan, including planning partners. The effort to include stakeholders in this process included stakeholder participation on the Steering Committee. The Steering Committee consisted of a diverse group of stakeholders, including planning partner representatives, citizens, local members of the business community, members of academia, government representatives and members of the emergency management community.

Questionnaire

A hazard mitigation plan questionnaire (see Figure 3 -1) was developed by the planning team with guidance from the Steering Committee. The questionnaire was used to gauge household preparedness for natural hazards and the level of knowledge of tools and techniques that assist in reducing risk and loss from natural hazards. This questionnaire was designed to help identify areas vulnerable to one or more natural hazards. The answers to its 34 questions helped guide the Steering Committee in selecting goals, objectives and mitigation strategies. Hard copies of the questionnaire were made available upon request, and a web-based version was made available through the hazard mitigation plan website. Over 200 questionnaires were completed. The complete questionnaire and a summary of its findings can be found in Appendix D of this volume.

Public Meetings

A member of the planning team staffed a public information booth at the City of Auburn Disaster Preparedness Fair on September 15, 2013. Public open houses were held in the evenings on September 24, 2013 in Shoreline City Hall, on September 25, 2013 in the Kent Senior Activity Center, and on September 26, 2013 in the Evergreen Health Auditorium in Kirkland (see Figure 3 -2 through Figure 3 -5). The meeting format allowed attendees to examine maps and handouts and have direct conversations with project staff. Reasons for planning and information generated for the risk assessment were shared with attendees via a PowerPoint presentation. Tables were set up for each of the primary hazards to which King County is most vulnerable.



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King County

King County Regional Hazard Mitigation-Public Awareness Survey

1. Survey Introduction

A partnership of local governments and regional stakeholders in King County is working together to update the King County Regional Hazard Mitigation Plan. The purpose of this plan is to help local governments reduce the exposure of County residents to risks from natural hazards, such as earthquakes and floods. By writing this plan, local governments are able to apply to Federal programs that may provide money that can be used to reduce risks before and after natural disasters. This plan was first created in 2004 and was updated in 2009.

We need your help to plan for the possibility of future disasters. We would like to find projects that will help reduce or avoid impacts from natural hazard events. The following questions will help us measure how much local citizens already know about disaster-related issues and will help us identify areas where we need to improve. The information you provide will help us organize activities and prioritize projects to reduce the risk of injury or damage to property from future hazard events.

The survey consists of about 30 questions, and there is an opportunity to provide additional comments at the end. It should take less than 10 minutes to complete the survey and it is anonymous. When you have finished the survey, please click "Done" on the final page.

The King County Hazard Mitigation Planning Partnership thanks you for taking the time to participate in this important information-gathering process.

***1. Do you live in King County?**

- Yes
- No

Other (please specify)

***2. In what ZIP code is your home mailing address?**

3. In the past 20 years, have you or anyone in your household experienced any of the following hazards within King County? (Choose all that apply)

- Avalanche
- Dam/Levee Failure
- Drought
- Earthquake
- Flood
- River/Stream Bank Erosion
- Hazardous Materials Spill/Release
- Other (please specify)
- Household Fire
- Landslide
- Severe Weather (wind, lightning, winter storm, etc.)
- Tsunami
- Wildland Fires
- None

Next

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Figure 3-1. Sample Web Page from Questionnaire

Figure 3-2. Attendees Listen to Presentation at Shoreline Public Meeting

Figure 3-3. Stakeholder Display at Public Open House

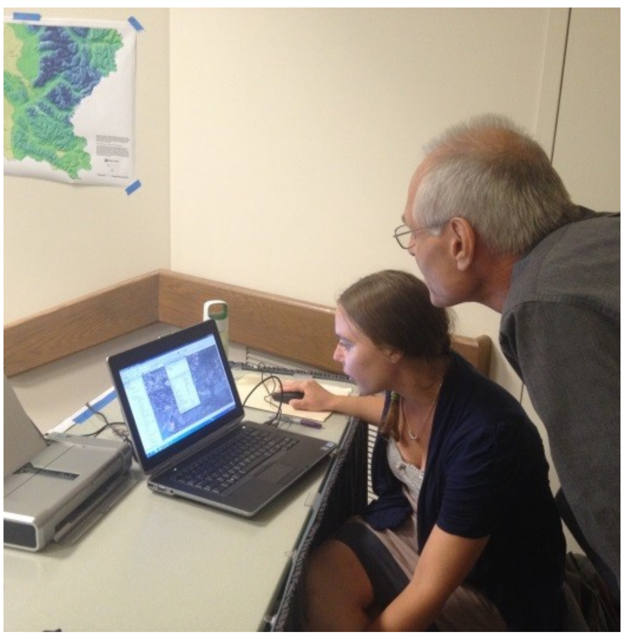


Figure 3-4. Citizen Learns about Risk at Hazus Workstation

Figure 3-5. Citizens View Hazard Maps at Public Open House

A Hazus-MH workstation allowed citizens to see information on their property, including exposure and damage estimates for earthquake and flood hazard events (Figure 3 -6). Participating property owners were provided printouts of this information for their properties or could sign up to have information emailed to them. This tool was effective in illustrating risk to the public. More than 50 Hazus workstation reports were emailed to citizens following the public meetings. Planning partners and the planning team were present to answer questions. Each citizen attending the open houses was asked to complete a questionnaire, and each was given an opportunity to provide written comments to the Steering Committee. Local media outlets were informed of the open houses by a press release from the County.

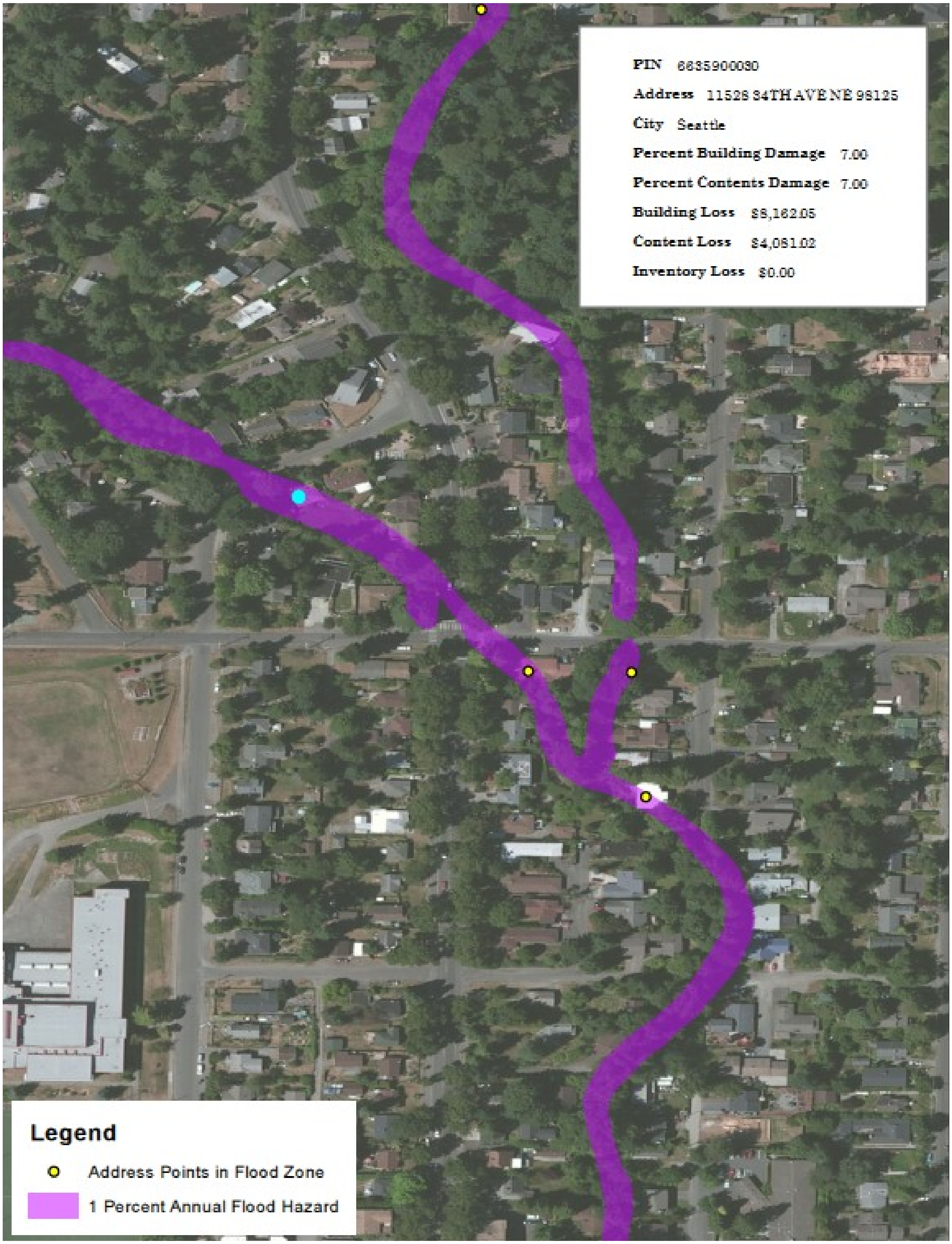


Figure 3-6. Example Hazus Workstation Output

Posters and Information Cards

To help advertise the survey and the public meetings, posters were printed that advertised both public outreach initiatives (see Figure 3 -7). These posters were provided to all planning partners and were posted throughout the county. In addition, over 2000, two-sided, pocket information cards were printed and disseminated to all Steering Committee members and Planning partners (see Figure 3 -8). The cards provided a QR code link to the survey and a web link to the hazard mitigation plan website, and advertised the public meetings.

Figure 3-7. Poster Advertising Public Meetings and Survey

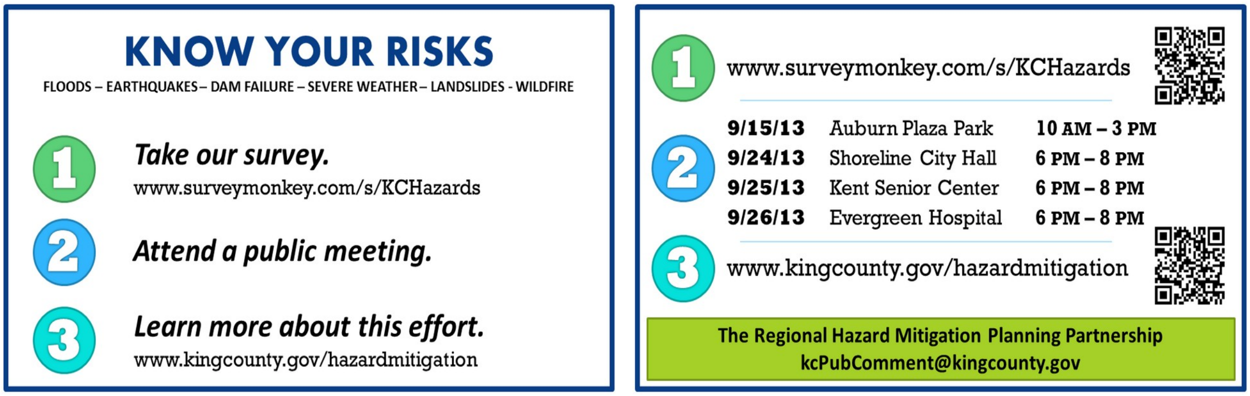


Figure 3-8. Pocket Information Card (Front and Back)

Press Releases

Press releases were distributed over the course of the plan's development as key milestones were achieved and prior to each public meeting. The planning effort received the following press coverage:

- Press release material published in the Shoreline City News on September 20, 2013
- Press release material published in the Kirkland Reporter on August 30, 2013. http://www.kirklandreporter.com/community/221842301.html
- Press release material published in the Bothell/Kenmore Kirkland Reporter on September 23, 2013. http://www.bothell-reporter.com/news/224892422.html
- Press release material published on SnoValleyStar.com on July 7, 2014. http://snovalleystar.com/2014/07/07/public-input-wanted-on-hazard-mitigation-plan

Internet

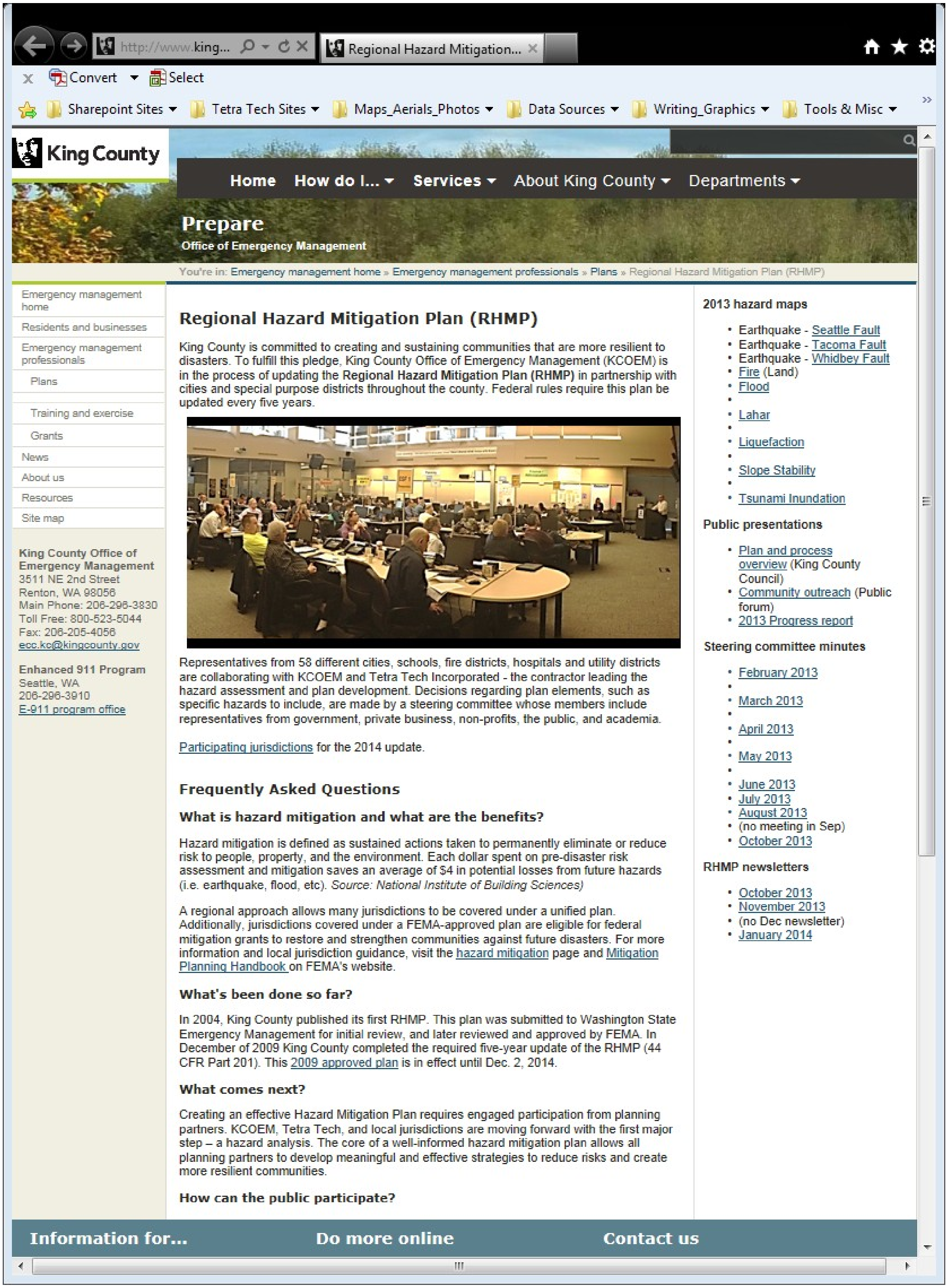
At the beginning of the plan development process, a website was created to keep the public posted on plan development milestones and to solicit relevant input (see Figure 3 -9):

> http://www.kingcounty.gov/safety/prepare/EmergencyManagementProfessionals/Plans/RegionalHazardMitigationPlan.aspx

The site's address was publicized in all press releases, mailings, questionnaires and public meetings. Information on the plan development process, the Steering Committee, the questionnaire and phased drafts of the plan was made available to the public on the site throughout the process. The County intends to keep a website active after the plan's completion to keep the public informed about successful mitigation projects and future plan updates.

Informational Bulletins

As a way to the keep the large planning partnership and the public apprised of plan development milestones, six bulletins were distributed by the planning team over the course of the planning process. Bulletins provided to each planning partner helped to keep the large partnership involved in the process and informed them when planning partner deliverables were due. These bulletins were also posted on the hazard mitigation plan website to update the public on the planning process and its milestones. The bulletins are presented in Appendix C.



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King County

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Prepare

Office of Emergency Management

You're in: Emergency management home » Emergency management professionals » Plans » Regional Hazard Mitigation Plan (RHMP)

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King County Office of Emergency Management
3511 NE 2nd Street
Renton, WA 98056
Main Phone: 206-296-3830
Toll Free: 800-523-5044
Fax: 206-205-4056
ecc.kc@kingcounty.gov

Enhanced 911 Program
Seattle, WA
206-296-3910
E-911 program office

Regional Hazard Mitigation Plan (RHMP)

King County is committed to creating and sustaining communities that are more resilient to disasters. To fulfill this pledge, King County Office of Emergency Management (KCOEM) is in the process of updating the **Regional Hazard Mitigation Plan (RHMP)** in partnership with cities and special purpose districts throughout the county. Federal rules require this plan be updated every five years.

Representatives from 58 different cities, schools, fire districts, hospitals and utility districts are collaborating with KCOEM and Tetra Tech Incorporated - the contractor leading the hazard assessment and plan development. Decisions regarding plan elements, such as specific hazards to include, are made by a steering committee whose members include representatives from government, private business, non-profits, the public, and academia.

Participating jurisdictions for the 2014 update.

Frequently Asked Questions

What is hazard mitigation and what are the benefits?

Hazard mitigation is defined as sustained actions taken to permanently eliminate or reduce risk to people, property, and the environment. Each dollar spent on pre-disaster risk assessment and mitigation saves an average of $4 in potential losses from future hazards (i.e. earthquake, flood, etc). *Source: National Institute of Building Sciences)*

A regional approach allows many jurisdictions to be covered under a unified plan. Additionally, jurisdictions covered under a FEMA-approved plan are eligible for federal mitigation grants to restore and strengthen communities against future disasters. For more information and local jurisdiction guidance, visit the hazard mitigation page and Mitigation Planning Handbook on FEMA's website.

What's been done so far?

In 2004, King County published its first RHMP. This plan was submitted to Washington State Emergency Management for initial review, and later reviewed and approved by FEMA. In December of 2009 King County completed the required five-year update of the RHMP (44 CFR Part 201). This 2009 approved plan is in effect until Dec. 2, 2014.

What comes next?

Creating an effective Hazard Mitigation Plan requires engaged participation from planning partners. KCOEM, Tetra Tech, and local jurisdictions are moving forward with the first major step – a hazard analysis. The core of a well-informed hazard mitigation plan allows all planning partners to develop meaningful and effective strategies to reduce risks and create more resilient communities.

How can the public participate?

2013 hazard maps

- Earthquake - Seattle Fault
- Earthquake - Tacoma Fault
- Earthquake - Whidbey Fault
- Fire (Land)
- Flood
- Lahar
- Liquefaction
- Slope Stability
- Tsunami Inundation

Public presentations

- Plan and process overview (King County Council)
- Community outreach (Public forum)
- 2013 Progress report

Steering committee minutes

- February 2013
- March 2013
- April 2013
- May 2013
- June 2013
- July 2013
- August 2013
- (no meeting in Sep)
- October 2013

RHMP newsletters

- October 2013
- November 2013
- (no Dec newsletter)
- January 2014

Information for... | Do more online | Contact us

Figure 3-9. Sample Page from Hazard Mitigation Plan Web Site

3.8.2 Public Involvement Results

By engaging the public through the public involvement strategy, the concept of mitigation was introduced to the public, and the Steering Committee received feedback that was used in developing the components of the plan. Details of attendance and comments received are summarized in Table 3 -9.

**TABLE 3-9.
SUMMARY OF PUBLIC MEETINGS**

Date	Location	Number of Citizens in Attendance	Number of Comments Received	Number of Questionnaires Received
September 24, 2013	Shoreline City Hall	38	2	6
September 25, 2013	Kent Senior Activity Center	30	1	1
September 26, 2013	Evergreen Health Auditorium	17	0	1
July 7, 2014	Snoqualmie City Hall	8	0	—
July 9, 2014	Issaquah City Hall	6	3	—
July 10, 2014	Duvall Visitor Center	2	0	—
July 10, 2014	Shoreline City Hall	25	4	—
Total		0	0	**8**

3.9 PLAN DEVELOPMENT CHRONOLOGY/MILESTONES

Table 3 -10 summarizes important milestones in the development of the plan.

**TABLE 3-10.
PLAN DEVELOPMENT MILESTONES**

Date	Event	Description	Attendance
2012			
10/11	Contractor Support	County advertises solicitation for contractor support for the plan update	N/A
12/2	Select Tetra Tech to facilitate plan development	Facilitation contractor secured	N/A
12/15	Identify planning team	Formation of the planning team	N/A
2013			
1/24	Planning partner kickoff meeting	Second meeting with potential planning partners. Attendees were advised of planning partner expectations and asked to formally commit to the process. Steering Committee volunteers were solicited.	61
2/13	Steering Committee formed	Planning partners nominated potential committee members. The planning team received commitments from 14 members, finalizing the formation of the Steering Committee.	N/A

**TABLE 3-10.
PLAN DEVELOPMENT MILESTONES**

Date	Event	Description	Attendance
2/20	Steering Committee Meeting #1	• Review purposes for update • Organize Steering Committee • Plan review • Public Involvement Strategy	21
2/25	Planning partnership finalized	Deadline for submittal of letters of intent to participate in the planning effort.	N/A
3/21	Steering Committee meeting #2	• Risk assessment update • Plan review observations • Critical Facilities • Guiding Principle/Mission Statement • Public Outreach	20
4/16	Steering Committee meeting #3	• Risk assessment update • “Other” Hazards of Concern • Define Critical Facilities • Guiding principle/ mission statement • Public Outreach Strategy update	12
5/21	Steering Committee meeting #4	• Reviewed and approved previous month’ minutes • Reported non-meeting hours • Reviewed current risk assessment update • Approve a Critical Facility definition • Approve a guiding principle/vision statement • Introduction to the goal setting exercise • Finalize the survey	15
6/18	Steering Committee meeting #5	• Reviewed and approved previous month’ minutes • Reported non-meeting hours • Reviewed current risk assessment update • Identified earthquake scenarios • Been introduced to the objectives exercise • Identified a plan maintenance strategy • Discussed public outreach strategy	15
7/16	Steering Committee meeting #6	• Reviewed and approved previous month’s minutes • Reported non-meeting hours • Reviewed current risk assessment update • Selected objectives • Confirmed plan maintenance strategy • Discussed public outreach strategy	12
8/20	Steering Committee meeting #7	• Reviewed and approved previous month’s minutes • Reported non-meeting hours • Previewed Maps • Confirmed objectives • Confirmed plan maintenance strategy • Discussed public outreach strategy • Discussed planning partner participation	12
9/2	Public Outreach	Press release advertising public meetings and website disseminated to all media outlets.	N/A

**TABLE 3-10.
PLAN DEVELOPMENT MILESTONES**

Date	Event	Description	Attendance
10/15	Steering Committee meeting #8	• Reviewed and approved previous month’s minutes • Reported non-meeting hours • Reviewed the status of the Risk Assessment • Reviewed Status of Jurisdictional Annex deployment • Reviewed Phase 1, Public Outreach results • Confirmed revised plan maintenance strategy • Identified Strengths, Weaknesses, Obstacles and opportunities with King County	10
11/12	Jurisdictional Annex Workshops (Round 1)	Mandatory session for planning partners. Workshop focused on how to complete the jurisdictional annex template. Two sessions were held. One for municipal governments and one for special purpose districts.	31
11/13	Jurisdictional Annex Workshops (Round 2)	Mandatory session for planning partners. Workshop focused on how to complete the jurisdictional annex template. Two sessions were held. One for municipal governments and one for special purpose districts.	37
2014			
2/25	Steering Committee meeting #9	• Reviewed and approved previous month’s minutes • Reported non-meeting hours • Reviewed status of Jurisdictional Annex deployment • Confirmed revised Plan Maintenance Strategy • Identified County Wide Initiatives • Discussed next steps	13
3/19	Stakeholder Engagement	Presentation on earthquake scenarios assessed by plan given at the Resilient King County workshop #1	67
4/4	Draft Plan	Internal review draft provided by planning team to Steering Committee	N/A
4/15	Steering Committee meeting #10	Discussion and comments of Volume I internal review draft. Discussion of public comment, plan review and plan approval processes.	11
4/16	Stakeholder Engagement	Presentation on earthquake scenarios assessed by plan given at the Resilient King County workshop #2	45
6/27	Public Comment Period	Initial public comment period of draft plan opens. Draft plan posted on plan website with press release notifying public of plan availability	N/A
7/7	Public Outreach	Final public meeting on Draft Plan – City of Snoqualmie	8
7/9	Public Outreach	Final public meeting on Draft Plan – City of Issaquah	6
7/10	Public Outreach	Final public meeting on Draft Plan – City of Duvall	2
7/10	Public Outreach	Final public meeting on Draft Plan – City of Shoreline	25
7/31	Regulatory Review Submittal	Final draft plan submitted to Washington State for review and approval	N/A
8/13	Adoption	Adoption window of final plan opens	N/A
2015			

TABLE 3-10.
PLAN DEVELOPMENT MILESTONES

Date	Event	Description	Attendance
5/1	Plan Approval	Final plan approved by FEMA	N/A

CHAPTER 4.

GUIDING PRINCIPLE, GOALS AND OBJECTIVES

Hazard mitigation plans must identify goals for reducing long-term vulnerabilities to identified hazards (44 CFR Section 201.6(c)(3)(i)). The Steering Committee established a guiding principle, a set of goals and measurable objectives for this plan, based on data from the preliminary risk assessment and the results of the public involvement strategy. The guiding principle, goals, objectives and actions in this plan all support each other. Goals were selected to support the guiding principle. Objectives were selected that met multiple goals. Actions were prioritized based on the action meeting multiple objectives.

4.1 GUIDING PRINCIPLE

A guiding principle focuses the range of objectives and actions to be considered. This is not a goal because it does not describe a hazard mitigation outcome, and it is broader than a hazard-specific objective. The guiding principle for the King County Regional Hazard Mitigation Plan Update is as follows:

> King County is a region that promotes community resilience by eliminating or reducing risks and adverse impacts from hazards, while encouraging hazard mitigation activities by all sectors.

4.2 GOALS

The following are the mitigation goals for this plan:

1. Protect life and property.
2. Increase public awareness of hazards and mitigation opportunities.
3. Protect, restore and enhance environmental quality.
4. Leverage partnering opportunities.
5. Enhance planning activities.
6. Develop and implement cost-effective mitigation strategies.
7. Promote a sustainable economy.

The effectiveness of a mitigation strategy is assessed by determining how well these goals are achieved.

4.3 OBJECTIVES

Each selected objective meets multiple goals, serving as a stand-alone measurement of the effectiveness of a mitigation action, rather than as a subset of a goal. The objectives also are used to help establish priorities. The objectives are as follows:

1. Increase the resilience of critical facilities, infrastructure and government operations to ensure continuity of operations during and after a hazard event.
2. Consider the impacts of hazards in all planning mechanisms that address current and future land uses and integrate hazard mitigation goals and objectives into other existing plans and programs within the planning area.

3. Develop, improve and protect systems that provide early warnings, emergency response communications and evacuation procedures.
4. Use the best available data, science and technologies to improve understanding and stakeholder awareness of the location and potential impacts of hazards, the vulnerability of building types and community development patterns, and the measures needed to mitigate hazards.
5. Seek feasible mitigation projects that provide the highest degree of hazard protection with the best benefit-cost ratio.
6. Emphasize the hazard mitigation message in and promote the value of public outreach and education programs, such as Take Winter By Storm and What to Do to Make it Through.
7. Improve coordination among all sectors to mitigate hazards.
8. Reduce hazard-related risks and vulnerability to potentially isolated populations within the planning area.
9. Retrofit, purchase or relocate structures in high hazard areas, including those known to be repetitively damaged.
10. Strengthen codes to improve the hazard resilience of new construction.
11. Leverage social networks and other social capital mechanisms to educate the public and stakeholders and promote resilience.
12. Seek actions that protect or improve the environment for future environmental conditions.
13. Form private/public partnerships to leverage and share resources.
14. Partner with the private sector, including small businesses, to promote hazard mitigation as part of standard business practice.
15. Educate businesses about contingency planning countywide, targeting small businesses and those located in high risk areas, and promote employee education about disaster preparedness while on the job and at home.

PART 2—
RISK ASSESSMENT

CHAPTER 5.

IDENTIFIED HAZARDS OF CONCERN AND RISK ASSESSMENT METHODOLOGY

Risk assessment is the process of measuring the potential loss of life, personal injury, economic injury, and property damage resulting from natural hazards. It allows emergency management personnel to establish early response priorities by identifying potential hazards and vulnerable assets. The process focuses on the following elements:

- Hazard identification—Use all available information to determine what types of disasters may affect a jurisdiction, how often they can occur, and their potential severity.
- Vulnerability identification—Determine the impact of natural hazard events on the people, property, environment, economy and lands of the region.
- Cost evaluation—Estimate the cost of potential damage or cost that can be avoided by mitigation.

The risk assessment for this hazard mitigation plan update evaluates the risk of natural hazards prevalent in the planning area and meets requirements of the DMA (44 CFR, Section 201.6(c)(2)).

5.1 IDENTIFIED HAZARDS OF CONCERN

For this plan, the Steering Committee considered the full range of natural hazards that could impact the planning area and then listed hazards that present the greatest concern. The process incorporated review of state and local hazard planning documents, as well as information on the frequency, magnitude and costs associated with hazards that have impacted or could impact the planning area. Anecdotal information regarding natural hazards and the perceived vulnerability of the planning area's assets to them was also used. Based on the review, this plan addresses the following hazards of concern:

- Avalanche
- Dam failure
- Earthquake
- Flood
- Landslide
- Severe weather
- Severe winter weather
- Tsunami
- Volcano
- Fire

With the exception of dam failure, this plan does not provide a full risk assessment of technological hazards and human-caused hazards. However, Chapter 18. provides a qualitative discussion of the following additional hazards, referred to in this plan as hazards of interest:

- Health hazards (epidemic, pandemic and bioterrorism)

- Cybersecurity
- Terrorism (vehicle-borne improvised explosive device).

5.2 METHODOLOGY

The risk assessments in Chapter 8. through Chapter 17. describe the risks associated with each identified hazard of concern. Each chapter describes the hazard, the planning area's vulnerabilities, and probable event scenarios. The following steps were used to define the risk of each hazard:

- Identify and profile each hazard—The following information is given for each hazard:
  - Geographic areas most affected by the hazard
  - Event frequency estimates
  - Severity estimates
  - Warning time likely to be available for response.
- Determine exposure to each hazard—Exposure was determined by overlaying hazard maps with an inventory of structures, facilities, and systems to determine which of them would be exposed to each hazard. For each identified hazard of concern, the best available existing data delineating a hazard area was selected. Data sets were evaluated based on scale, age and source. Additionally, data available in a GIS-compatible format with coverage of the full extent of the planning area were preferentially selected for use in the analysis.
- Assess the vulnerability of exposed facilities—Vulnerability of exposed structures and infrastructure was determined by interpreting the probability of occurrence of each event and assessing structures, facilities, and systems that are exposed to each hazard. Tools such as GIS and FEMA's hazard-modeling program called Hazus-MH were used to perform this assessment for the flood, dam failure and earthquake hazards. Outputs similar to those from Hazus were generated for other hazards, using maps generated by the Hazus program.

5.3 RISK ASSESSMENT TOOLS

5.3.1 Mapping

A review of national, state and county databases was performed to locate available spatially based data relevant to this planning effort. Maps were produced using GIS software to show the spatial extent and location of identified hazards when such data was available. These maps are included in the hazard profile chapters of this document and many of them are available on the King County Regional Hazard Mitigation Plan website. Information regarding the data sources and methodologies employed in these mapping efforts is located in Appendix E.

5.3.2 Dam Failure, Earthquake and Flood—Hazus-MH

Overview

In 1997, FEMA developed the standardized Hazards U.S., or Hazus, model to estimate losses caused by earthquakes and identify areas that face the highest risk and potential for loss. Hazus was later expanded into a multi-hazard methodology, Hazus-MH, with new models for estimating potential losses from hurricanes and floods.

Hazus-MH is a GIS-based software program used to support risk assessments, mitigation planning, and emergency planning and response. It provides a wide range of inventory data, such as demographics, building stock, critical facility, transportation and utility lifeline, and multiple models to estimate

potential losses from natural disasters. The program maps and displays hazard data and the results of damage and economic loss estimates for buildings and infrastructure. Its advantages include the following:

- Provides a consistent methodology for assessing risk across geographic and political entities.
- Provides a way to save data so that it can readily be updated as population, inventory, and other factors change and as mitigation planning efforts evolve.
- Facilitates the review of mitigation plans because it helps to ensure that FEMA methodologies are incorporated.
- Supports grant applications by calculating benefits using FEMA definitions and terminology.
- Produces hazard data and loss estimates that can be used in communication with local stakeholders.
- Is administered by the local government and can be used to manage and update a hazard mitigation plan throughout its implementation.

Levels of Detail for Evaluation

Hazus-MH provides default data for inventory, vulnerability and hazards; this default data can be supplemented with local data to provide a more refined analysis. The model can carry out three levels of analysis, depending on the format and level of detail of information about the planning area:

- **Level 1**—All of the information needed to produce an estimate of losses is included in the software's default data. This data is derived from national databases and describes in general terms the characteristic parameters of the planning area.
- **Level 2**—More accurate estimates of losses require more detailed information about the planning area. To produce Level 2 estimates of losses, detailed information is required about local geology, hydrology, hydraulics and building inventory, as well as data about utilities and critical facilities. This information is needed in a GIS format.
- **Level 3**—This level of analysis generates the most accurate estimate of losses. It requires detailed engineering and geotechnical information to customize it for the planning area.

Application for This Plan

The Hazus model was used as follows for the hazards evaluated in this plan:

- **Flood**—A Level 2, user-defined analysis was performed for general building stock and for critical facilities and infrastructure. GIS building and assessor data (replacement cost values and detailed structure information) were loaded into Hazus-MH. An updated inventory was used in place of the Hazus-MH defaults for essential facilities, transportation and utilities. Current planning area flood mapping was used to delineate flood hazard areas and estimate potential losses from the 100- and 500-year flood events.
- **Dam Failure**—The basis for this analysis was the Lake Youngs dam failure inundation mapping. This data was imported into Hazus-MH and a Level 2 analysis was run using the flood methodology described above.
- **Earthquake**—A Level 2 analysis was performed to assess earthquake risk and exposure. Earthquake shake maps and probabilistic data prepared by the U.S. Geological Survey (USGS) were used for the analysis of this hazard. An updated general building stock inventory was developed using replacement cost values and detailed structure information from assessor tables.

An updated inventory of essential facilities, transportation and utility features was used in place of the Hazus-MH defaults. Three scenario events and two probabilistic events were modeled:

– The scenario events were a Magnitude-7.2 event on the Seattle Fault, a Magnitude-7.4 event on the South Whidbey Island Fault and a Magnitude-7.1 event on the Tacoma Fault.

– The standard Hazus analysis for the 100- and 500-year probabilistic events was run.

5.3.3 Landslide, Tsunami, Severe Weather, Severe Winter Weather, Wildfire and Volcano

For landslide, tsunami, severe weather, severe winter weather, volcano and wildfire, historical data was not adequate to model future losses. Hazus-MH has an application for the tsunami hazard, but it was not used for this plan update because available tsunami mapping of the Puget Sound region is limited. A Washington state-led effort to map this hazard in Puget Sound is incomplete. Current mapping covers only the City of Seattle, which is not participating as a planning partner in this update. A qualitative approach was used instead.

Hazus-MH is able to map hazard areas and calculate exposures if geographic information is available on the locations of the hazards and inventory data. Areas and inventory susceptible to some of the hazards of concern were mapped and exposure was evaluated. For other hazards, a qualitative analysis was conducted using the best available data and professional judgment. Locally relevant information was gathered from a variety of sources. Frequency and severity indicators include past events and the expert opinions of geologists, emergency management specialists and others. The primary data source was the King County GIS database, augmented with state and federal data sets. Additional data sources for specific hazards were as follows:

- **Landslide**—Three sources of data were utilized to approximate the extent and location of landslide hazard areas. Landslide location data was obtained from the Washington Department of Natural Resources and a landslide hazard dataset was obtained from King County. Potential landslide hazard areas dataset was created using surface geology and digital elevation model based on LiDAR data provided by King County. The combination of the three data sources were used to identify the extent and location of the landslide hazard areas. It should be noted that this level of detail is considered approximate, awareness zone mapping and is not considered to be suitable for use in a regulatory context. As of the completion of the planning process, King County was embarking on a landslide hazard identification process that will strive to generate detailed landslide hazard mapping that is suitable for use in a regulatory context. Future updates to this plan can be enhanced by this data once it becomes available.
- **Severe Weather and Severe Winter Weather**—Severe weather data was downloaded from the Natural Resources Conservation Service and the National Renewable Energy Laboratory.
- **Volcano**—Volcanic hazard data was obtained from the Washington Department of Natural Resources.
- **Wildfire**—Information on wildfire hazards areas was provided by U.S. Geological Survey and Washington Department of Natural Resources.
- **Tsunami**—Information on tsunami hazard areas was provided by Washington State Department of Natural Resources.

5.3.4 Avalanche

The risk assessment methodologies used for this plan focus on damage to structures. Because there are very few structures in the county exposed to impacts from avalanches, the risk assessment was more limited and qualitative than the assessment for the other hazards of concern.

5.3.5 Limitations

Loss estimates, exposure assessments and hazard-specific vulnerability evaluations rely on the best available data and methodologies. Uncertainties are inherent in any loss estimation methodology and arise in part from incomplete scientific knowledge concerning natural hazards and their effects on the built environment. Uncertainties also result from the following:

- Approximations and simplifications necessary to conduct a study
- Incomplete or outdated inventory, demographic or economic parameter data
- The unique nature, geographic extent and severity of each hazard
- Mitigation measures already employed
- The amount of advance notice residents have to prepare for a specific hazard event.

These factors can affect loss estimates by a factor of two or more. Therefore, potential exposure and loss estimates are approximate and should be used only to understand relative risk. Over the long term, King County and its planning partners will collect additional data to assist in estimating potential losses associated with other hazards.

KING COUNTY PROFILE

King County is located in Western Washington between Puget Sound and the Cascade Mountains (see Figure 6 -10). It is the most populous of Washington's 39 counties and has 39 incorporated areas. Seattle is the county seat.

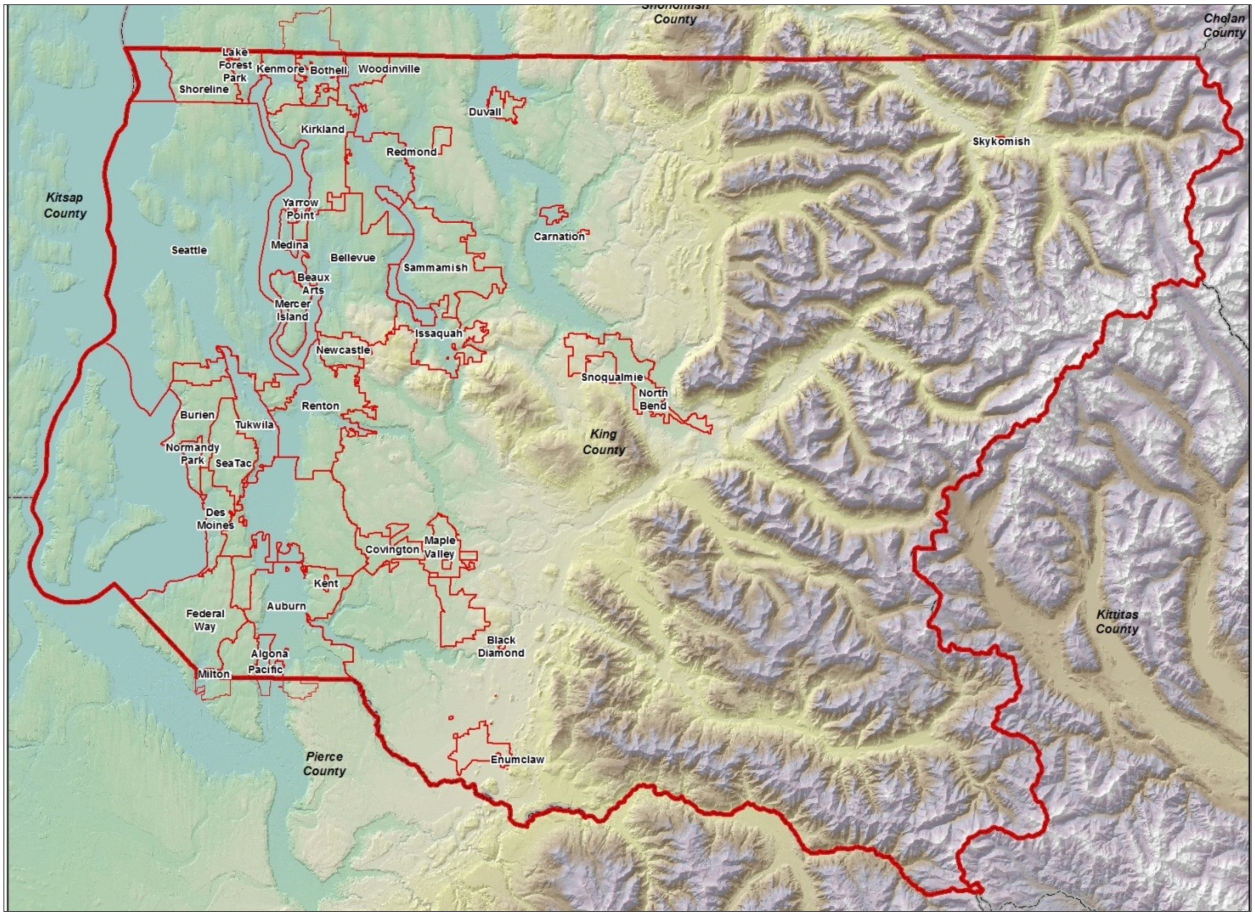


Figure 6-10. Main Features of the Planning Area

King County has more than 1.9 million residents. The major population centers are located in the western portion of the county along the shores of Puget Sound and Lake Washington. The most populous cities are Seattle with more than 600,000 residents, Bellevue and Kent with more than 100,000 residents, and Renton, Federal Way and Auburn with more than 60,000 residents (King County, 2011). Jurisdictions in the area are close together and form the Seattle-Bellevue-Everett metropolitan region. Approximately 13 percent of the county population lives in unincorporated areas (King County, 2011).

Although there is considerable development in the county, most of the land area consists of natural resource and rural lands. Incorporated areas cover 19 percent of the total land area (404 square miles) and the remaining 81 percent (1,711 square miles) is unincorporated (King County Department of Permitting and Environmental Review, 2013). The central and eastern sections have few urbanized areas.

The aerospace, export manufacturing and natural resource industries have long been the major economic drivers for the county. The importance of the high tech industry has increased in recent years, and that industry now a base industry for the county. The county is also home to several major health care facilities and educational institutions, including the University of Washington.

Elevations in the county range from sea level in the west to the almost 8,000-foot peak of Mt. Daniel in the east. The geological features of the county tend to run north-south, which makes east-west travel more complex than north-south travel. The county's physical geography includes a portion of the Cascade Mountain Range, the Issaquah Alps and the Sammamish Plateau. Water features include Puget Sound, Lake Washington, Lake Sammamish, and Lake Union. The Snoqualmie, Green, White and Cedar rivers all flow out of the Cascades toward Puget Sound. The county also includes Mercer Island in Lake Washington and Vashon-Maury Island in Puget Sound.

6.1 JURISDICTIONS AND ATTRACTIONS

The county is bounded by Puget Sound on the west, Snohomish County on the north, Chelan and Kittitas Counties on the east, and Pierce County on the south. Three of its incorporated cities (Auburn, Milton and Pacific) extend into Pierce County, and one (Bothell) extends into Snohomish County.

Jurisdictions in the county range in size from Seattle with over 600,000 residents to smaller communities such as Skykomish with approximately 500 residents. The western part of King County includes the communities of Algona, Auburn, Beaux Arts Village, Bellevue, Bothell, Burien, Clyde Hill, Covington, Des Moines, Federal Way, Hunts Point, Kenmore, Kent, Kirkland, Lake Forest Park, Medina, Mercer Island, Milton, Newcastle, Normandy Park, Pacific, Redmond, Renton, SeaTac, Seattle, Shoreline, Tukwila, Woodinville and Yarrow Point. Communities in the central area include Black Diamond, Carnation, Duvall, Enumclaw, Issaquah, Maple Valley, North Bend, Sammamish and Snoqualmie. Skykomish, located in the northeastern portion of the county is the only incorporated community in eastern King County.

Two Native American tribes have lands in the county. The Muckleshoot Reservation is located in south-central King County near Auburn. The Snoqualmie Tribe does not have a dedicated reservation, but its members have traditionally lived in the northeastern portion of the county.

King County features abundant open space and recreational opportunities abound. Municipal park systems in the county include a wide array of attractions such as Seattle's Discovery Park. King County's Parks and Recreation Division maintains over 26,000 acres of recreational areas. Cougar Mountain National Wildland Park is located in the central portion of the county, and most of the eastern portion of the county is in the Mount Baker-Snoqualmie National Forest.

6.2 HISTORICAL OVERVIEW

The following historical overview is summarized from the HistoryLink.org website (Long, 2006).

The King County area's indigenous peoples were the Duwamish Tribe living on or near the site of Seattle, the Snoqualmie Tribe in what is now eastern King County, and the Muckleshoot Tribe on the Green and White Rivers. During the late 1700s, introduced diseases affected these tribes. British Captain George Vancouver explored Puget Sound in 1792, and saw evidence of smallpox among the Indians. By the time settlers arrived in 1852, the Indian population was much reduced.

The first settlers were farmers led by Luther Collins. The Collins Party claimed land up the winding Duwamish River (later Georgetown) on September 14, 1851. A week later the Denny Party arrived on

Alki Point (future West Seattle). In the spring of 1852, most of the Denny Party moved to the shore of the deep and well-sheltered harbor of Elliott Bay, on the site of Pioneer Square in today's downtown Seattle.

The Oregon Territorial Legislature created King County on December 22, 1852. Less than three months later, in 1853, Washington Territory came into being and King County was part of it. King County was originally named for William Rufus DeVane King, who was U.S. vice president at the time. In 1986 the County changed its namesake to Martin Luther King Jr.

In eastern King County, hop-growing, logging, and coal mining developed during the 1870s. After the Great Northern Railroad chose Tacoma for its terminal over Seattle, Seattleites built the Seattle & Walla Walla, which became profitable hauling coal from Newcastle to the Seattle waterfront. By 1875 coal superseded lumber as King County's first industry. By the 1880s sawmills supported towns like Bothell, Duvall, and Enumclaw, as well as Seattle's 10 sawmills. In 1900, Frederick Weyerhaeuser purchased 1,406 square miles of Washington state timberlands. The Weyerhaeuser later incorporated and eventually absorbed smaller timber firms. Commercial canneries were located in Seattle's Belltown and in Kent. William Boeing founded the predecessor of Boeing Airplane Co. in 1917. America's entrance into World War II jump-started the economy, following the Great Depression, into wartime production of airplanes and battleships. In 1975, Bill Gates and Paul Allen founded Microsoft, which came to equal Boeing in its impact on the county.

Governance of King County has evolved. In 1968, voters approved a new Home Rule Charter eliminating several elected posts, including coroner and sheriff, and replacing the County's three commissioners with an elected county executive and a nine-member county council representing districts, while retaining an elected prosecutor and assessor. The post of sheriff became elective in 1996 and all positions are partisan except it. The King County Council expanded to 13 members in 1993 but shrank back to nine a dozen years later. Development proceeds in accordance with the Comprehensive Growth Plan (1994), which favors urban density to preserve green space.

6.3 MAJOR PAST HAZARD EVENTS

Presidential disaster declarations are typically issued for hazard events that cause more damage than state and local governments can handle without assistance from the federal government, although no specific dollar loss threshold has been established for these declarations. A presidential disaster declaration puts federal recovery programs into motion to help disaster victims, businesses and public entities. Some of the programs are matched by state programs. The planning area has experienced 31 events since 1956 for which presidential disaster declarations were issued. These events are listed in Table 6 -11.

Review of these events helps identify targets for risk reduction and ways to increase a community's capability to avoid large-scale events in the future. Still, many natural hazard events do not trigger federal disaster declaration protocol but have significant impacts on their communities. These events are also important to consider in establishing recurrence intervals for hazards of concern.

6.4 PHYSICAL SETTING

6.4.1 Geology

The Pacific Northwest has a complex geological history that was shaped by geological processes over the past 200 million years. The Cascade Mountains in the eastern portion of the county were formed 4 to 7 million years ago as a result of a fold caused by the steep descent of the Juan De Fuca plate below the continental margin. The friction of this descent created two folds that formed both the Cascade and Olympic Mountain Ranges. This friction is also the source of the regional subduction-zone earthquake regime present today (Townsend and Figge, 2002).

TABLE 6-11.
FEDERAL DISASTER DECLARATIONS FOR EVENTS AFFECTING KING COUNTY

Disaster Number	Incident Description	Event Begin Date
DR-50	Flood	2/25/1956
DR-70	Floods	3/6/1957
DR-137	Severe storms	10/20/1962
DR-146	Floods	3/2/1963
DR-185	Heavy rains & flooding	12/29/1964
DR-196	Earthquake	5/11/1965
DR-328	Heavy rains & flooding	3/24/1972
DR-492	Severe storms & flooding	12/13/1975
DR-545	Severe storms, mudslides, & flooding	12/10/1977
DR-612	Storms, high tides, mudslides & flooding	12/31/1979
DR-623	Volcanic eruption, Mt. St. Helens	5/21/1980
DR-757	Severe storms & flooding	1/16/1986
DR-784	Severe storms & flooding	11/22/1986
DR-852	Severe storms & flooding	1/6/1990
DR-883	Severe storms & flooding	11/9/1990
DR-896	Severe storms & high tides	12/20/1990
DR-981	Severe storms & high wind	1/20/1993
DR-1079	Severe storms, high wind, and flooding	11/7/1995
DR-1100	High winds, severe storms and flooding	1/26/1996
DR-1159	Severe winter storms, land & mudslides, flooding	12/26/1996
DR-1172	Heavy rains, snow melt, flooding, land & mud slides	3/18/1997
DR-1361	Earthquake	2/28/2001
DR-1499	Severe storms and flooding	10/15/2003
EM-3227	Hurricane Katrina evacuation	8/29/2005
DR-1671	Severe storms, flooding, landslides, and mudslides	11/2/2006
DR-1682	Severe winter storm, landslides, and mudslides	12/14/2006
DR-1734	Severe storms, flooding, landslides, and mudslides	12/1/2007
DR-1817	Severe winter storm, landslides, mudslides, and flooding	1/6/2009
DR-1825	Severe winter storm and record and near record snow	12/12/2008
DR-1963	Severe winter storm, flooding, landslides, and mudslides	1/11/2011
DR-4056	Severe winter storm, flooding, landslides, and mudslides	1/14/2012

Note: Presidential disaster declarations prior to 1964 were declared for entire states. Pre-1964 events listed here are for Washington. Declarations from 1964 on are county-specific, and those listed here are for King County.
Source: (Federal Emergency Management Agency, 2012).

Active volcanoes have been present along the north-south Cascade Arc for million years, and the remnants of former volcanoes make up the bedrock of the current Cascade chain. Volcanoes in the range are still active, although their presence as a result of the fold is merely incidental to the older chain. The eruptions of Mount Rainier, located in neighboring Pierce County, have also shaped the geography of the area. Major eruptions in the past 5,000 years have resulted in substantial mudflows that reached the shores of Puget Sound. The potential for future eruptions near highly populated areas makes Mount Rainier the most dangerous volcano in North America (Townsend and Figge, 2002).

In addition to tectonic movements, repeated glacier movement across the region over the past 2 million years affected the geological features of the western portion of King County. The most recent period of glaciation was the Vashon period, which occurred during the late Pleistocene. Glaciers in this period advanced into Washington from Canada about 18,000 years ago and retreated 10, 000 to 12,000 years ago. These glacial episodes carved out Puget Sound and Lake Washington and deposited glacial till across the region (Townsend and Figge, 2002).

6.4.2 Soils

The soils and land types of western King County formed during the glacial advancement and retreat during the Vashon period. Four major types of material were left by the glacier: till, recessional outwash, pro-glacial lacustrine and outwash sediments. After glaciers retreated, alluvium accumulated in the valleys and a mudflow from Mount Rainier covered a portion of the southern part of the county. No soil survey information is available for the eastern portion of the county; however, most development is concentrated within the western county, where, according to the U.S. Natural Resources Conservation Service’s soil survey, there are seven soil associations (Snyder et al., 1973):

- **Alderwood Association**—Occurs on large tracts of land in the northern and southern parts of the county. These areas are moderately well drained and roll into hilly soils that have dense, very slowly permeable glacial till on uplands and terraces. This association covers 52 percent of the study area
- **Oridia-Seattle-Woodinville Association**—Occurs in southern and northern portions of the county. It is somewhat poorly drained to very poorly drained. These nearly level soils occur in major stream valleys and are the best-suited areas for crop production in the survey area. This association covers 11 percent of the survey area.
- **Buckley-Alderwood Association**—Occurs on glacial till plains and upland in the southeastern portion of the county. It is comprised of poorly drained to moderately well drained soils that are nearly level to rolling. These areas also have dense, slowly permeable and very slowly permeable glacial till. This association covers 7 percent of the study area.
- **Everett Association—**Occurs in the southeastern portion of the county and in smaller areas scattered in the northern portion. They are composed of somewhat excessively drained, gravelly, gently rolling soils underlain by sand and gravel on terraces. This association covers 14 percent of the survey area.
- **Beausite-Alderwood Association**—Occurs in the central and eastern portions of the survey area. It is characterized by well drained and moderately well drained soils that very from gently rolling to very steep soils that have sandstone or shale or dense very slowly permeable glacial till on uplands. This association covers 9 percent of the survey area.
- **Alderwood–Kitsap-Indianola Association**—Occurs in the northern half of the county. It is characterized by moderately-well drained, nearly level to steep soils that have very slowly permeable glacial till or glacial lake deposits and somewhat excessively drained, rolling, deep sandy soils, on uplands and terraces. This association covers 5 percent of survey area.

- **Puget-Earlmont-Snohomish Association**—Occurs in three areas in the Sammamish and Snoqualmie valleys in the northern half of the county. It is poorly drained to somewhat poorly drained, nearly level soils that have layers of peat within a few feet of the surface in major stream valleys. This association covers 3 percent of the study area.

6.4.3 Seismic Features

King County is located on the Pacific Ring of Fire. This geological area is known for volcanic activity and frequent seismic activity. Washington State is located in close proximity to the convergence of several tectonic plates including the Pacific, North American, and Juan de Fuca. There are a substantial number of identified faults within the county and small earthquakes occur regularly. In general earthquakes in the area arise from three sources. The oblique subduction of the Juan de Fuca plate below the Puget Sound region can produce events as large as magnitude 7. The faults on the North American plate can produce moderate to large events on either side of the Cascades. Additionally, great earthquakes, which can have magnitudes of 9.0 or greater, can occur at the boundaries of these plates generally referred to as the Cascadia Subduction Zone (USGS, 2012).

There are a significant number of active faults and folds in the Puget Sound lowlands, including the Tacoma Fault, Seattle Fault, Darrington-Devil’s Mountain Fault, Utsalady Point Fault and the Southern Whidbey Island Fault. Many of the faults run from east to west and are over 20 miles in length. An event on any of these faults would likely impact King County. The U.S. Geological Survey has estimated the probability of one or more earthquakes of Richter magnitude 7.0 or higher occurring in the Puget Sound area within the next 30 years to be 18 to 20 percent.

6.4.4 Climate

Climate across King County depends on factors such as elevation and distance from Puget Sound. Precipitation in the area is concentrated in the winter. In the Puget Sound lowlands, annual precipitation ranges from 30 to 45 inches annually. Snowfall is relatively rare, with an average of 10 to 20 inches per year. Generally, any snowfall melts within a day or two of accumulation. January average temperatures range from 28ºF to 45ºF., and July average temperatures range from 50ºF to 78ºF. Most of the lowland area is in the “rain shadow” of the Olympic Mountains. Precipitation totals and temperature variations increase from west to east across the lowlands (Western Regional Climate Center, 2014).

On the western slopes and foothills of the Cascade Range in the eastern portion of the county, precipitation averages 90 inches. Snowfall averages increase with elevation to 50 inches at 500 to 800 feet. Temperature ranges are similar to those of the lowlands with January ranges between 25ºF and 45ºF and July ranges between 50ºF and 80ºF. In the western Cascades, precipitation is heavy, with annual amounts ranging from 60 to 100 inches or more. Annual snowfall averages 50 to 75 inches in the lower elevations and can be as high as 600 inches between 4,000 and 5,500 feet. Peaks above 7,000 feet generally remain snowcapped throughout the summer. January temperatures range from 20ºF to 40ºF, dependent on elevation. Summer temperatures at these elevations are variable. Above 4,000 feet, temperatures may remain below freezing even in mid-summer. As a general rule, temperatures decreases by 3ºF for every 1,000-foot increase in elevation (Western Regional Climate Center, 2014).

Average climate conditions across King County for temperature, precipitation and wind are shown on Figure 6 -11 through Figure 6 -14.

Insert Average Maximum Temperature Map

Figure 6-11. Annual Average Maximum Temperature, 1981 – 2010

Insert Average Minimum Temperature Map

Figure 6-12. Annual Average Minimum Temperature, 1981 – 2010

Insert Average Precipitation Map

Figure 6-13. Annual Average Precipitation, 1981 – 2010

Insert Average Wind Map

Figure 6-14. Wind Power Class at 50-Meter Height

6.5 LAND USE

Table 6 -12 shows current land use in the planning area based on King, Pierce and Snohomish County parcel data. Land use information is analyzed in this plan for each identified hazard that has a defined spatial extent and location. For hazards that lack this spatial reference, the following information serves as a baseline estimate of land use and exposure for the planning area. The distribution of land uses within the county will change over time.

TABLE 6-12.
PRESENT LAND USE IN PLANNING AREA

Present Use Classification	Area (acres)	% of total
Agriculture	1,260	0.09%
Church, Welfare or Religious Service	2,739	0.21%
Commercial	27,788	2.08%
Education	8,108	0.61%
Governmental Services	3,126	0.23%
Industrial/Manufacturing	9,101	0.68%
Medical/Dental Services	869	0.07%
Mixed Use Development (Residential & Commercial)	562	0.04%
Mortuary/Cemetery/Crematory	932	0.07%
Nursing Home/Retirement Facility	628	0.05%
Park/Open Space/Golf Course	29,185	2.19%
Residential	276,893	20.77%
Terminal or Marina	5,118	0.38%
Utility/Easement/Right of Way	10,840	0.81%
Water/Tideland/Wetland	558	0.04%
Uncategorized (includes vacant and resource lands)	955,666	71.67%
Total	0	**100%**

Note: Summarized from King, Pierce and Snohomish County parcel data. Acreage covers only mapped parcels and thus excludes many rights of way and major water features.

6.6 CRITICAL FACILITIES AND INFRASTRUCTURE

Critical facilities and infrastructure are all facilities and infrastructure, whether publicly or privately owned, that are vital to the King County planning area's ability to provide essential services and protect life and property. A short- or long-term loss of a critical facility would result in a severe economic, health and welfare, life-sustainment or other catastrophic impact. Critical facilities can be grouped in three categories:

- Facilities that are essential to the ability to respond to, mitigate and recover from the impacts of natural hazards, including those potentially used as shelters
- Facilities that need early warning to enable them to prepare for and respond to the impacts of natural hazards

- Facilities that by the nature of their operations, produce, manufacture or store materials that create an exposure to secondary hazards of concern.

Under the King County regional hazard mitigation plan definition, critical facilities include but are not limited to the following:

- Police stations, fire stations, city/county government facilities (including those that house critical information technology and communication infrastructure), vehicle and equipment storage facilities, and emergency operations centers needed for disaster response before, during, and after hazard events
- Hospitals, care facilities, and housing, including facilities likely to contain occupants who may not be sufficiently mobile to avoid death or injury during a hazard event
- Other healthcare providers such as ambulatory care, free-standing surgery centers and urgent care centers that play a role in responding to regional disasters involving casualties
- Public and private utilities and infrastructure vital to maintaining or restoring normal services to areas damaged by hazard events, including, but not limited to, the following:
  - Public and private water supply infrastructure, water and wastewater treatment facilities and infrastructure, potable water pumping, flow regulation, distribution and storage facilities and infrastructure
  - Public and private power generation (electrical and non-electrical), regulation and distribution facilities and infrastructure
  - Data and server communication facilities
  - Structures that manage or limit the impacts of natural hazards such as regional flood conveyance systems, potable water trunk main interconnect systems and redundant pipes crossing fault lines and reservoirs
  - Transportation systems that convey vital supplies and services to and throughout the community.
- Educational facilities, including K-12, universities and community college.
- Public gathering places that could be used as evacuation centers during large-scale disasters.
- Infrastructure designed to help safely convey high-water from an event source to the perimeter of the planning area.
- Structures or facilities that produce, use, or store highly volatile, flammable, explosive, toxic, and/or water-reactive materials.

The default Hazus database was distributed to planning partners for review and update. Default information was used for jurisdictions not participating in the planning effort. Table 6 -13 and Table 6 -14 provide summaries of the general types of critical facilities and infrastructure, respectively, in each municipality and unincorporated county areas. These tables indicate the location of critical facilities and infrastructure, not jurisdictional ownership. All critical facilities/infrastructure were analyzed in Hazus to help rank risk and identify mitigation actions. The risk assessment for each hazard qualitatively discusses critical facilities with regard to that hazard.

Figure 6 -15 and Figure 6 -16 show the location of critical facilities and infrastructure in unincorporated areas of the county. Critical facilities within the cities participating in this plan are shown in maps for each city provided in Volume 2. Due to the sensitivity of this information, a detailed list of facilities is not provided. The list is on file with each planning partner.

TABLE 6-13.
CRITICAL FACILITIES BY JURISDICTION AND CATEGORY

	Medical and Health	Government Functions	Protective Function	Schools	Hazmat	Other Critical Function	Total
Algona	0	0	1	1	0	1	**3**
Auburn	10	2	7	32	13	23	**87**
Beaux Arts Village	0	0	0	0	0	0	**0**
Bellevue	7	1	17	44	1	28	**98**
Black Diamond	0	0	2	1	0	0	**3**
Bothell	11	6	4	18	0	6	**45**
Burien	28	1	10	23	0	11	**73**
Carnation	3	0	2	4	0	0	**9**
Clyde Hill	0	1	2	4	0	0	**7**
Covington	15	3	2	7	0	20	**47**
Des Moines	2	0	3	11	0	5	**21**
Duvall	1	0	2	3	0	4	**10**
Enumclaw	3	0	3	11	0	5	**22**
Federal Way	59	1	5	35	0	19	**119**
Hunts Point	0	0	0	0	0	0	**0**
Issaquah	26	1	5	8	2	14	**56**
Kenmore	0	0	5	6		3	**14**
Kent	46	2	20	29	23	25	**145**
Kirkland	56	1	8	30	7	39	**141**
Lake Forest Park	0	0	2	2	0	1	**5**
Maple Valley	6	2	7	4	0	6	**25**
Medina	0	0	1	3	0	2	**6**
Mercer Island	9	1	3	34	0	4	**51**
Milton	4	0	1	3	0	0	**8**
Newcastle	1	0	2	2	0	2	**7**
Normandy Park	0	1	1	1	0	0	**3**
North Bend	7	1	3	3	0	2	**16**
Pacific	0	0	2	1	0	0	**3**
Redmond	22	2	4	28	31	31	**118**
Renton	41	1	8	24	9	22	**105**
Sammamish	3	0	6	14	0	3	**26**
SeaTac	9	1	5	11	0	3	**29**
Seattle	72	2	55	170	91	132	**522**
Shoreline	13	2	12	25		20	**72**
Skykomish	0	1	2	1	0	1	**5**
Snoqualmie	2	0	2	10	0	3	**17**
Tukwila	12	1	9	0	9	5	**36**
Woodinville	3	1	2	5	0	2	**13**
Yarrow Point	0	0	0	0	0	23	**23**
Unincorporated	17	0	52	88	1	0	**158**
Total	0	0	0	0	0	0	0

**TABLE 6-14.
CRITICAL INFRASTRUCTURE BY JURISDICTION AND CATEGORY**

	Bridges	Transportation	Water Supply	Wastewater	Power	Communications	Dams	Total
Algona	1	0	0	27	2	0	1	**31**
Auburn	25	3	16	0	1	4	2	**51**
Beaux Arts Village	0	0	2	0	0	0	0	**2**
Bellevue	71	3	0	3	1	7	7	**92**
Black Diamond	0	0	6	1	0	0	0	**7**
Bothell	22	1	26	5	0	3	3	**60**
Burien	8	2	32	10	0	0	0	**52**
Carnation	0	0	0	0	0	0	0	**0**
Clyde Hill	0	0	6	0	0	0	0	**6**
Covington	11	0	3	9	2	0	0	**25**
Des Moines	9	0	3	29	0	0	0	**41**
Duvall	1	0	3	9	0	0	0	**13**
Enumclaw	0	0	0	1	0	0	0	**1**
Federal Way	15	1	2	1	0	0	5	**24**
Hunts Point	1	0	0	0	0	0	0	**1**
Issaquah	27	0	22	3	1	0	1	**54**
Kenmore	13	4	0	1	1	0	1	**20**
Kent	43	5	17	12	2	0	5	**84**
Kirkland	18	2	3	4	2	2	0	**31**
Lake Forest Park	2	0	1	0	0	0	1	**4**
Maple Valley	3	0	14	4	1	0	0	**22**
Medina	3	0	0	0	0	0	0	**3**
Mercer Island	10	3	0	2	0	1	0	**16**
Milton	3	0	0	0	0	0	0	**3**
Newcastle	1	0	0	0	0	0	1	**2**
Normandy Park	1	0	0	2	0	0	0	**3**
North Bend	14	0	5	2	1	0	0	**22**
Pacific	4	0	0	1	0	0	0	**5**
Redmond	18	6	16	16	2	0	0	**58**
Renton	41	3	10	2	1	0	0	**57**
Sammamish	2	0	1	1	0	0	1	**5**
SeaTac	19	6	15	3	0	0	2	**45**
Seattle	184	259	8	32	4	14	11	**512**
Shoreline	9	0	2	19	2	1	2	**35**
Skykomish	2	1	1	0	0	0	0	**4**
Snoqualmie	6	0	6	16	4	0	5	**37**
Tukwila	52	8	5	15	0	1	0	**81**
Woodinville	3	0	3	3	0	0	0	**9**
Yarrow Point	1	0	0	0	0	0	0	**1**
Unincorporated	418	10	126	33	5	31	28	**651**
Total	0	0	0	0	0	0	0	0

Insert Critical Facilities Map

Figure 6-15. Planning Area Critical Facilities

Insert Critical Infrastructure Map

Figure 6-16. Planning Area Critical Infrastructure

6.7 DEMOGRAPHICS

Some populations are at greater risk from hazard events because of decreased resources or physical abilities. Elderly people, for example, may be more likely to require additional assistance. Research has shown that people living near or below the poverty line, the elderly (especially older single men), the disabled, women, children, ethnic minorities and renters all experience, to some degree, more severe effects from disasters than the general population. These vulnerable populations may vary from the general population in risk perception, living conditions, access to information before, during and after a hazard event, capabilities during an event, and access to resources for post-disaster recovery. Indicators of vulnerability—such as disability, age, poverty, and minority race and ethnicity—often overlap spatially and often in the geographically most vulnerable locations. Detailed spatial analysis to locate areas where there are higher concentrations of vulnerable community members would assist the County in extending focused public outreach and education to these most vulnerable citizens.

6.7.1 Population Characteristics

Information about the composition of the population and how it has changed in the past and how it may change in the future is a critical part of planning because it directly relates to land needs such as housing, industry, public services, and transportation. King County is the most populous of Washington's 39 counties. The Washington Office of Financial Management estimated the total county population at 1,981,900 as of April 2013 (Washington State Office of Financial Management, 2012).

Population changes are useful socio-economic indicators. A growing population generally indicates a growing economy, while a decreasing population signifies economic decline. City annexations and incorporations of new cities have sharply reduced the unincorporated-area population of King County in recent decades. Table 6 -15 shows the population of incorporated municipalities and the combined unincorporated areas in King County since 1990. In 2012, 13 percent of the planning area's residents lived outside incorporated areas, compared to 34 percent in 1990. Overall growth in incorporated area population was 71 percent from 1990 to 2012, while the unincorporated areas of the county saw a population decrease of 50 percent during the same timeframe.

Figure 6 -17 shows the overall population growth rate in the planning area from 1910 to 2010 compared to that of the State of Washington. For most of that period, King County's 10-year growth rate has been slightly higher than the statewide rate; the county's population growth was lower than the state's in the 1930s and 1970s and in the past two decades.

6.7.2 Income

In the United States, individual households are expected to use private resources to prepare for, respond to and recover from disasters to some extent. This means that households living in poverty are automatically disadvantaged when confronting hazards. Additionally, the poor typically occupy more poorly built and inadequately maintained housing. Mobile or modular homes, for example, are more susceptible to damage in earthquakes and floods than other types of housing.

In urban areas, the poor often live in older houses and apartment complexes, which are more likely to be made of un-reinforced masonry, a building type that is particularly susceptible to damage during earthquakes. Furthermore, residents below the poverty level are less likely to have insurance to compensate for losses incurred from natural disasters. This means that residents below the poverty level have a great deal to lose during an event and are the least prepared to deal with potential losses. Personal household economics significantly impact people's decisions on evacuation. Individuals who cannot afford gas for their cars will likely decide not to evacuate.

TABLE 6-15.
ANNUAL POPULATION DATA

	Population			
	1990[a]	2000[a]	2010[a]	2012[b]
Algona	1,694	2,460	3,014	3,070
Auburn[c]	33,650	43,047	70,180	71,240
Beaux Arts Village	303	307	299	300
Bellevue	86,872	109,827	122,363	124,600
Black Diamond	1,422	3,970	4,153	4,170
Bothell[c]	12,345	30,084	33,505	34,000
Burien	[d]	31,881	33,313	47,730
Carnation	1,243	1,893	1,786	1,785
Clyde Hill	2,957	2,890	2,984	2,980
Covington	[d]	13,783	17,575	17,760
Des Moines	17,283	29,267	29,673	29,700
Duvall	2,770	4,616	6,695	6,900
Enumclaw	7,227	11,116	10,669	11,030
Federal Way	67,535	83,259	89,306	89,460
Hunts Point	514	443	394	390
Issaquah	7,786	11,212	30,434	31,150
Kenmore	[d]	18,678	20,460	21,020
Kent	37,960	79,524	92,411	119,100
Kirkland	40,059	45,054	48,787	81,480
Lake Forest Park	3,372	12,871	12,598	12,640
Maple Valley	[d]	14,209	22,684	23,340
Medina	2,981	3,011	2,969	2,990
Mercer Island	20,816	22,036	22,699	22,690
Milton[c]	4,995	5,795	6,968	6,985
Newcastle	[d]	7,737	10,380	10,460
Normandy Park	6,709	6,392	6,335	6,350
North Bend	2,578	4,746	5,731	5,855
Pacific[c]	4,622	5,527	6,606	6,620
Redmond	35,800	45,256	54,144	55,360
Renton	41,688	50,052	90,927	93,910
Sammamish	[d]	34,104	45,780	47,420
SeaTac	22,701	25,496	26,909	27,210
Seattle	516,259	563,376	608,660	616,500
Shoreline	[d]	53,296	53,007	53,270
Skykomish	273	214	198	200
Snoqualmie	1,546	1,631	10,670	11,320
Tukwila	11,874	17,181	19,107	19,080
Woodinville	[d]	9,809	10,938	10,960
Yarrow Point	957	1,008	1,001	1,060
Unincorporated County	513,171	349,234	325,000	255,720
King County Total	**1,507,305**	**1,737,046**	**1,931,249**	**1,957,000**

a. 1990, 2000 and 2010 populations from U.S. Census data
b. 2012 population from post-census estimate developed by Washington Office of Financial Management
c. Auburn, Milton and Pacific populations include parts of Pierce County. Bothell population includes part of Snohomish County
d. City not yet incorporated in this year

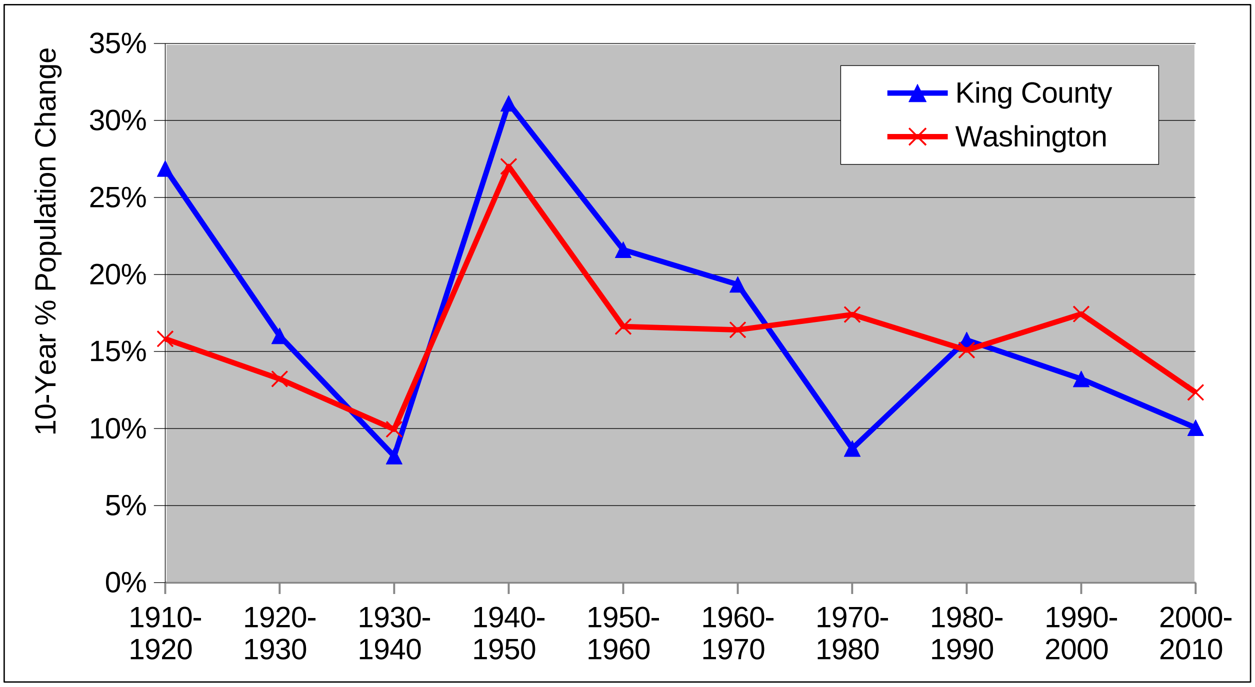


Figure 6-17. Washington and King County Population Growth

Based on U.S. Census Bureau American Community Survey estimates, per capita income in King County in 2011 was $38,286, and the median household income was $69,314. It is estimated that 33.0 percent of households receive an annual income of $100,000 or more. An estimated 16.9 percent of the households in the county made less than $25,000 per year in 2011, and 6.9 percent of families had incomes below the poverty level (U.S. Census Bureau, 2013).

6.7.3 Age Distribution

As a group, the elderly are more apt to lack the physical and economic resources necessary for response to hazard events and are more likely to suffer health-related consequences making recovery slower. They are more likely to be vision, hearing, and/or mobility impaired, and more likely to experience mental impairment or dementia. Additionally, the elderly are more likely to live in assisted-living facilities where emergency preparedness occurs at the discretion of facility operators. These facilities are typically identified as “critical facilities” by emergency managers because they require extra notice to implement evacuation. Elderly residents living in their own homes may have more difficulty evacuating their homes and could be stranded in dangerous situations. This population group is more likely to need special medical attention, which may not be readily available during natural disasters due to isolation caused by the event. Specific planning attention for the elderly is an important consideration given the current aging of the American population.

Children under 14 are vulnerable to disaster events because of their young age and dependence on others for basic necessities. Very young children may additionally be vulnerable to injury or sickness; this vulnerability can be worsened during a natural disaster because they may not understand the measures that need to be taken to protect themselves from hazards.

The overall age distribution for the planning area is illustrated in Figure 6 -18. Based on 2011 U.S. Census estimates, 11.0 percent of the county’s population is 65 or older and 17.8 percent is 14 or younger. The Census also estimates that 13.9 percent of the population under age 18 and 9.0 percent of

the population 65 or older lives in a household with income below the poverty line (U.S. Census Bureau, 2013).

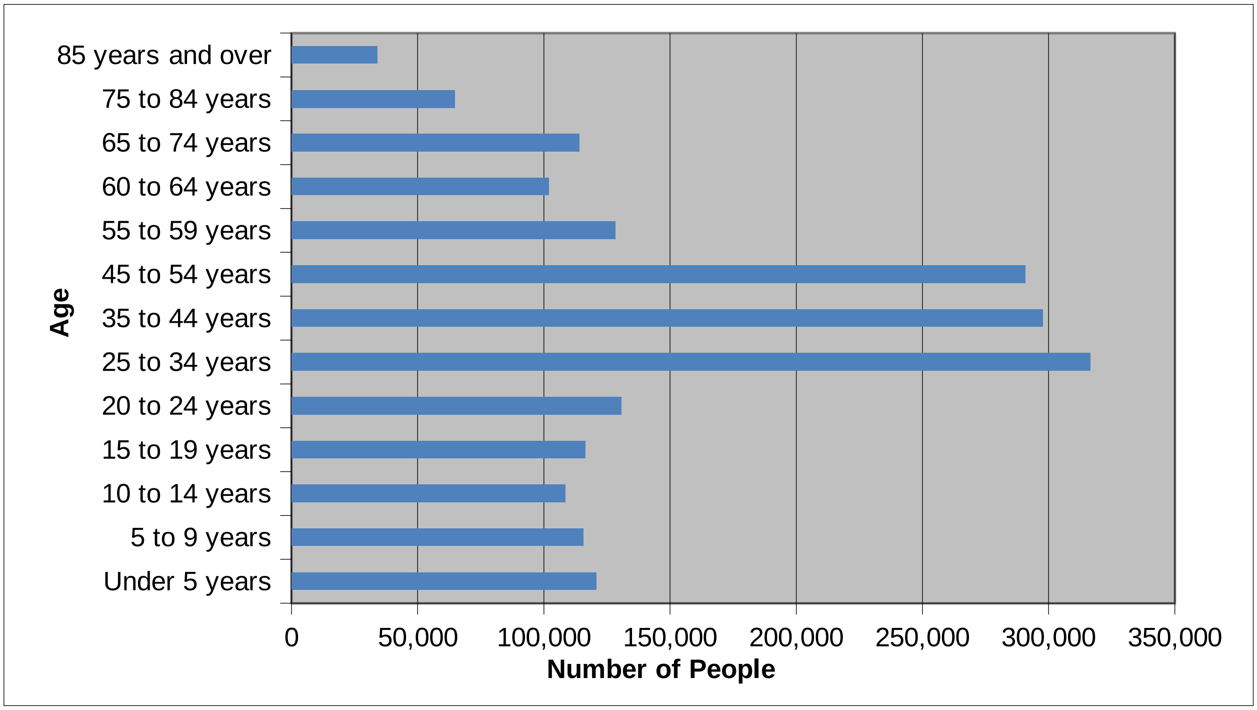


Figure 6-18. Planning Area Age Distribution

6.7.4 Race, Ethnicity and Language

Research shows that minorities are less likely to be involved in pre-disaster planning and experience higher mortality rates during a disaster event. Post-disaster recovery can be ineffective and is often characterized by cultural insensitivity. Since higher proportions of ethnic minorities live below the poverty line than the majority white population, poverty can compound vulnerability. According to the U.S. Census, the racial composition of the planning area is predominantly white, at 70.0 percent. The largest minority populations are Asian at 14.6 percent and African American at 6.2 percent. Figure 6 -19 shows the racial distribution in the planning area (U.S. Census Bureau, 2013).

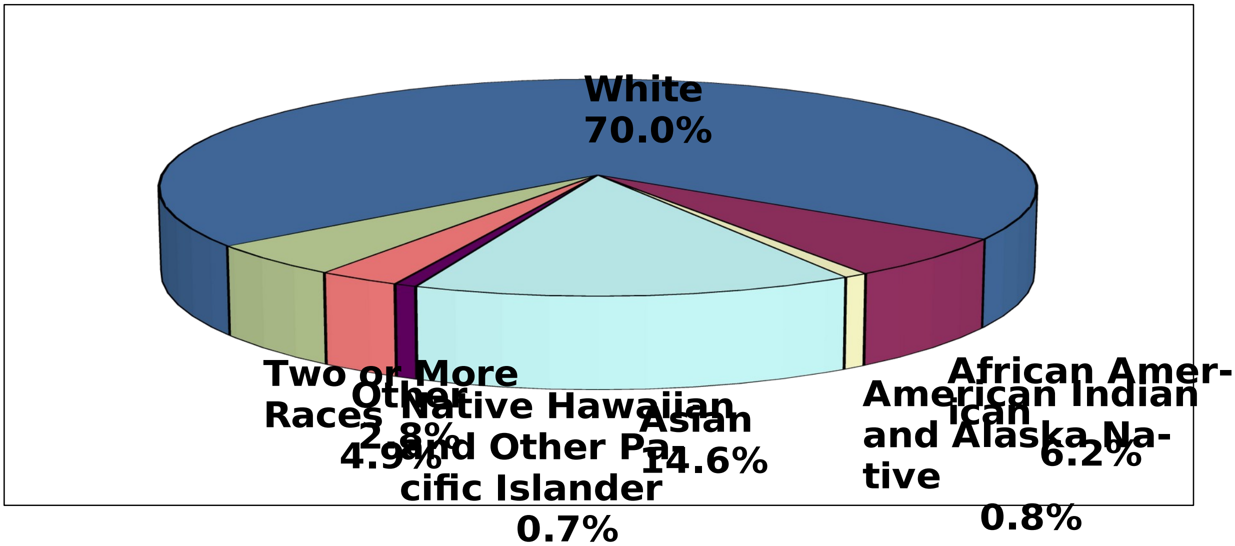


Figure 6-19. Planning Area Race Distribution

The planning area has a 20.4-percent foreign-born population. Other than English, the most commonly spoken languages in the planning area are Asian and Pacific Islander languages. The census estimates 10.9 percent of the residents speak English “less than very well” (U.S. Census Bureau, 2013).

6.7.5 Disabled Populations

The 2010 U.S. Census estimates that 54 million non-institutionalized Americans with disabilities live in the U.S. This equates to about one-in-five persons. People with disabilities are more likely to have difficulty responding to a hazard event than the general population. Local government is the first level of response to assist these individuals, and coordination of efforts to meet their access and functional needs is paramount to life safety efforts. It is important for emergency managers to distinguish between functional and medical needs in order to plan for incidents that require evacuation and sheltering. Knowing the percentage of population with a disability will allow emergency management personnel and first responders to have personnel available who can provide services needed by those with access and functional needs. According to U.S. Census estimates, 9.3 percent of the county population has some form of disability, including 35.6 percent of those 65 and older (U.S. Census Bureau, 2013).

6.8 ECONOMY

6.8.1 Industry, Businesses and Institutions

U.S. Census data for 2011 indicate that the industry with the greatest employment in King County is education, health care and social assistance (20.1 percent), followed by professional services (17.4 percent). Resource extraction (agriculture, forestry, fishing, hunting and mining) is the Census-designated industry with the least employment in the county (0.6 percent). Figure 6 -20 shows the breakdown of industry types in King County (U.S. Census Bureau, 2013).

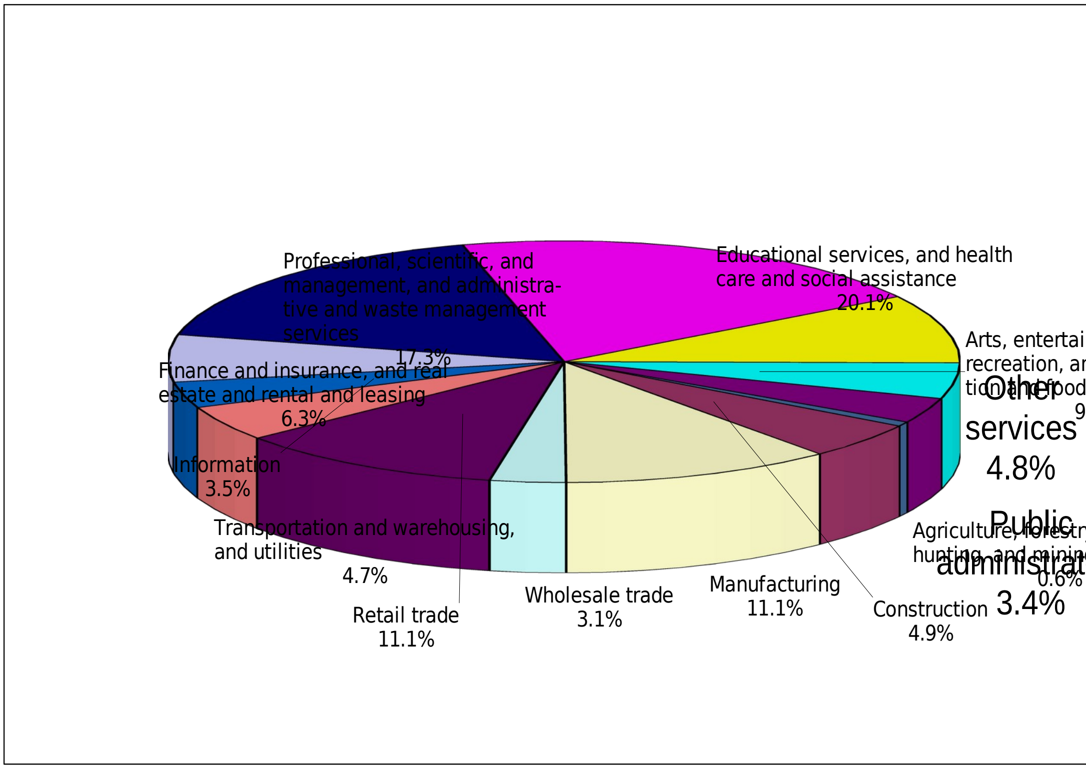


Figure 6-20. Industry in the Planning Area

King County benefits from a variety of business activity. Major businesses include the headquarters of eight Fortune 500 companies: Amazon.com, Costco Wholesale, Expediters International of Washington, Microsoft, Nordstrom, Paccar, Starbucks and Weyerhaeuser (CNN/Money, 2013). The Boeing Company also has major operations in the county. Major educational and research institutions in the county include the University of Washington, Seattle University, Harborview Medical Center and the Fred Hutchinson Cancer Research Center.

6.8.2 Employment Trends and Occupations

According to the 2011 American Community Survey, 70.3 percent of King County's population age 16 and older is in the labor force (U.S. Census Bureau, 2013). Figure 6 -21 compares Washington, King County and Seattle metropolitan area unemployment trends from 2000 through 2012 (Washington Employment Security Department, 2013). The unemployment rate in these areas was lowest in 2007, at close to 4 percent. It rose to between 9 and 10 percent in 2010 in response to the national recession, but has been falling again since then.

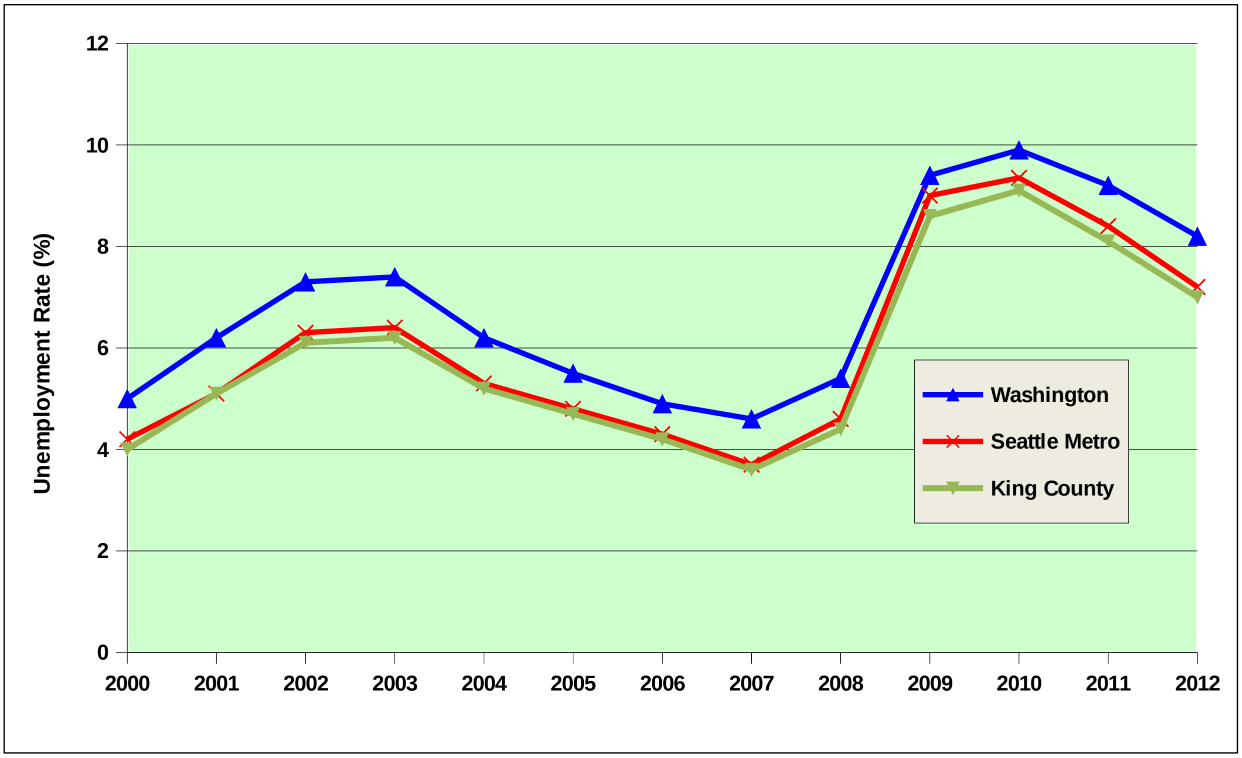


Figure 6-21. Washington, King County and Seattle Metropolitan Area Unemployment Rate

Almost half of employed workers in King County (48 percent) are in management, business science and arts occupations. Another 22 percent have sales and office jobs, and 15 percent are in service occupations (see Figure 6 -22) (U.S. Census Bureau, 2013). According to the Economic Development Council of Seattle and King County, the largest employer in the county is The Boeing Company, with 76,000 employees as of 2011, followed by Microsoft, with a 2011 employment in the county of 40,000, and the University of Washington, with 28,000 (Economic Development Council of Seattle and King County, 2013).

The U.S. Census estimates that 66.1 percent of King County workers commute alone to work (by car, truck or van), and mean travel time to work is 26.4 minutes (U.S. Census Bureau, 2013).

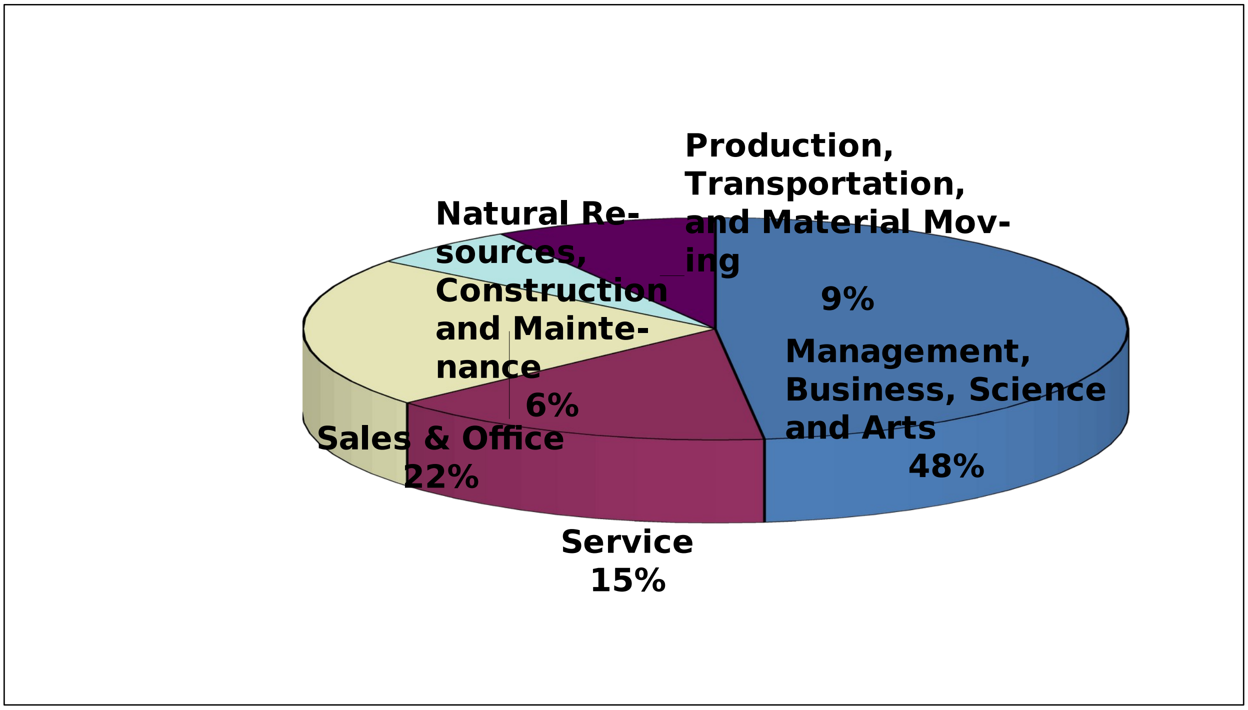


Figure 6-22. Occupations in the Planning Area

6.9 FUTURE TRENDS IN DEVELOPMENT

The municipal planning partners have adopted comprehensive plans that govern land-use decision- and policy-making in their jurisdictions. Decisions on land use are governed by these programs. This plan will work together with these programs to support wise land use in the future by providing vital information on the risk associated with natural hazards in the planning area.

All municipal planning partners will incorporate this hazard mitigation plan update in their comprehensive plans by reference. This will ensure that future development trends can be established with the benefits of the information on risk and vulnerability to natural hazards identified in this plan.

6.10 LAWS, ORDINANCES AND PROGRAMS

Existing laws, ordinances and plans at the federal, state and local level can support or impact hazard mitigation actions identified in this plan. Hazard mitigation plans are required to include a review and incorporation, if appropriate, of existing plans, studies, reports, and technical information as part of the planning process (44 CFR, Section 201.6(b)(3)). Pertinent federal and state laws are described below. Each planning partner has individually reviewed existing local plans, studies, reports, and technical information in its jurisdictional annex, presented in Volume 2.

6.10.1 Federal

Disaster Mitigation Act

The DMA is the current federal legislation addressing hazard mitigation planning. It emphasizes planning for disasters before they occur. It specifically addresses planning at the local level, requiring plans to be in place before Hazard Mitigation Grant Program funds are available to communities. This Plan is designed to meet the requirements of DMA, improving the planning partners’ eligibility for future hazard mitigation funds.

Endangered Species Act

The federal Endangered Species Act (ESA) was enacted in 1973 to conserve species facing depletion or extinction and the ecosystems that support them. The act sets forth a process for determining which species are threatened and endangered and requires the conservation of the critical habitat in which those species live. The ESA provides broad protection for species of fish, wildlife and plants that are listed as threatened or endangered. Provisions are made for listing species, as well as for recovery plans and the designation of critical habitat for listed species. The ESA outlines procedures for federal agencies to follow when taking actions that may jeopardize listed species and contains exceptions and exemptions. It is the enabling legislation for the Convention on International Trade in Endangered Species of Wild Fauna and Flora. Criminal and civil penalties are provided for violations of the ESA and the Convention.

Federal agencies must seek to conserve endangered and threatened species and use their authorities in furtherance of the ESA's purposes. The ESA defines three fundamental terms:

- **Endangered** means that a species of fish, animal or plant is "in danger of extinction throughout all or a significant portion of its range." (For salmon and other vertebrate species, this may include subspecies and distinct population segments.)
- **Threatened** means that a species "is likely to become endangered within the foreseeable future." Regulations may be less restrictive for threatened species than for endangered species.
- **Critical habitat** means "specific geographical areas that are…essential for the conservation and management of a listed species, whether occupied by the species or not."

Five sections of the ESA are of critical importance to understanding it:

- **Section 4: Listing of a Species**—The National Oceanic and Atmospheric Administration Fisheries Service (NOAA Fisheries) is responsible for listing marine species; the U.S. Fish and Wildlife Service is responsible for listing terrestrial and freshwater aquatic species. The agencies may initiate reviews for listings, or citizens may petition for them. A listing must be made "solely on the basis of the best scientific and commercial data available." After a listing has been proposed, agencies receive comment and conduct further scientific reviews for 12 to 18 months, after which they must decide if the listing is warranted. Economic impacts cannot be considered in this decision, but it may include an evaluation of the adequacy of local and state protections. Critical habitat for the species may be designated at the time of listing.
- **Section 7: Consultation**—Federal agencies must ensure that any action they authorize, fund, or carry out is not likely to jeopardize the continued existence of a listed or proposed species or adversely modify its critical habitat. This includes private and public actions that require a federal permit. Once a final listing is made, non-federal actions are subject to the same review, termed a "consultation." If the listing agency finds that an action will "take" a species, it must propose mitigations or "reasonable and prudent" alternatives to the action; if the proponent rejects these, the action cannot proceed.
- **Section 9: Prohibition of Take—**It is unlawful to "take" an endangered species, including killing or injuring it or modifying its habitat in a way that interferes with essential behavioral patterns, including breeding, feeding or sheltering.
- **Section 10: Permitted Take**—Through voluntary agreements with the federal government that provide protections to an endangered species, a non-federal applicant may commit a take that would otherwise be prohibited as long as it is incidental to an otherwise lawful activity (such as developing land or building a road). These agreements often take the form of a "Habitat Conservation Plan."

- **Section 11: Citizen Lawsuits**—Civil actions initiated by any citizen can require the listing agency to enforce the ESA's prohibition of taking or to meet the requirements of the consultation process.

With the listing of salmon and trout species as threatened or endangered, the ESA has impacted most of the Pacific Coast states. Although some of these areas have been more impacted by the ESA than others due to the known presence of listed species, the entire region has been impacted by mandates, programs and policies based on the presumption of the presence of listed species. Most West Coast jurisdictions must now take into account the impact of their programs on habitat.

The Clean Water Act

The federal Clean Water Act (CWA) employs regulatory and non-regulatory tools to reduce direct pollutant discharges into waterways, finance municipal wastewater treatment facilities, and manage polluted runoff. These tools are employed to achieve the broader goal of restoring and maintaining the chemical, physical, and biological integrity of the nation's surface waters so that they can support "the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water."

Evolution of CWA programs over the last decade has included a shift from a program-by-program, source-by-source, pollutant-by-pollutant approach to more holistic watershed-based strategies. Under the watershed approach, equal emphasis is placed on protecting healthy waters and restoring impaired ones. A full array of issues are addressed, not just those subject to CWA regulatory authority. Involvement of stakeholder groups in the development and implementation of strategies for achieving and maintaining water quality and other environmental goals is a hallmark of this approach.

National Flood Insurance Program

The National Flood Insurance Program (NFIP) provides federally backed flood insurance in exchange for communities enacting floodplain regulations. Participation and good standing under NFIP are prerequisites to grant funding eligibility under the Robert T. Stafford Act. The County and most of the partner cities for this plan participate in the NFIP and have adopted regulations that meet the NFIP requirements. At the time of the preparation of this plan, all participating jurisdictions in the partnership were in good standing with NFIP requirements.

6.10.2 State

Washington State Enhanced Mitigation Plan

The Washington State Enhanced Hazard Mitigation Plan approved by FEMA in 2010 provides guidance for hazard mitigation throughout Washington. The plan identifies hazard mitigation goals, objectives, actions and initiatives for state government to reduce injury and damage from natural hazards. By meeting federal requirements for an enhanced state plan (44 CFR parts 201.4 and 201.5), the plan allows the state to seek significantly higher funding from the Hazard Mitigation Grant Program following presidential declared disasters (20 percent of federal disaster expenditures vs. 15 percent with a standard plan).

Growth Management Act

The 1990 Washington State Growth Management Act (Revised Code of Washington (RCW) Chapter 36.70A) mandates that local jurisdictions adopt land use ordinances protect the following critical areas:

- Wetlands
- Critical aquifer recharge areas

- Fish and wildlife habitat conservation areas
- Frequently flooded areas
- Geologically hazardous areas.

The Growth Management Act regulates development in these areas, and therefore has the potential to affect hazard vulnerability and exposure at the local level.

Planning for natural hazards is an integral element of Washington’s statewide land use planning program under the Growth Management Act. Other related parts of the planning framework include the Shoreline Master Program rules and guidelines, which now provide for the integration of master programs and comprehensive plans. Natural Hazard Mitigation Elements are an optional element under the Growth Management Act. The continuing challenge faced by local officials and state government is to keep a network of coordinated local plans effective in responding to changing conditions and needs of communities. This is particularly true in the case of planning for natural and technological hazards, where communities must balance development pressures with detailed information on the nature and extent of hazards. Washington’s land use program has given its communities and citizens a unique opportunity to ensure that natural and technological hazards are addressed in the development and implementation of local comprehensive plans.

Shoreline Management Act

The 1971 Shoreline Management Act (RCW 90.58) was enacted to manage and protect the shorelines of the state by regulating development in the shoreline area. A major goal of the act is to prevent the “inherent harm in an uncoordinated and piecemeal development of the state’s shorelines.” Its jurisdiction includes the Pacific Ocean shoreline and the shorelines of Puget Sound, the Strait of Juan de Fuca, and rivers, streams and lakes above a certain size. It also regulates wetlands associated with these shorelines.

Washington State Building Code

The Washington State Building Code Council adopted the 2006 editions of national model codes, with some amendments. The Council also adopted changes to the Washington State Energy Code and Ventilation and Indoor Air Quality Code. Washington’s state-developed codes are mandatory statewide for residential and commercial buildings. The residential code exceeds the 2006 International Energy Conservation Code standards for most homes, and the commercial code meets or exceeds standards of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE 90.1-2004). For residential construction covered by ASHRAE 90.1-2007 (buildings with four or more stories), the state code is more stringent. The 2009 IBC went into effect as the Washington model code on July 1, 2010.

Comprehensive Emergency Management Planning

Washington’s Comprehensive Emergency Management Planning law (RCW 38.52) establishes parameters to ensure that preparations of the state will be adequate to deal with disasters, to ensure the administration of state and federal programs providing disaster relief to individuals, to ensure adequate support for search and rescue operations, to protect the public peace, health and safety, and to preserve the lives and property of the people of the state. It achieves the following:

- Provides for emergency management by the state, and authorizes the creation of local organizations for emergency management in political subdivisions of the state.
- Confers emergency powers upon the governor and upon the executive heads of political subdivisions of the state.

- Provides for the rendering of mutual aid among political subdivisions of the state and with other states and for cooperation with the federal government with respect to the carrying out of emergency management functions.
- Provides a means of compensating emergency management workers who may suffer any injury or death, who suffer economic harm including personal property damage or loss, or who incur expenses for transportation, telephone or other methods of communication, and the use of personal supplies as a result of participation in emergency management activities.
- Provides programs, with intergovernmental cooperation, to educate and train the public to be prepared for emergencies.

It is policy under this law that emergency management functions of the state and its political subdivisions be coordinated to the maximum extent with comparable functions of the federal government and agencies of other states and localities, and of private agencies of every type, to the end that the most effective preparation and use may be made of manpower, resources, and facilities for dealing with disasters.

Washington Administrative Code 118-30-060(1)

Washington Administrative Code (WAC) 118-30-060 (1) requires each political subdivision to base its comprehensive emergency management plan on a hazard analysis, and makes the following definitions related to hazards:

- Hazards are conditions that can threaten human life as the result of three main factors:
  - Natural conditions, such as weather and seismic activity
  - Human interference with natural processes, such as a levee that displaces the natural flow of floodwaters
  - Human activity and its products, such as homes on a floodplain.
- The definitions for hazard, hazard event, hazard identification, and flood hazard include related concepts:
  - A hazard may be connected to human activity.
  - Hazards are extreme events.

Hazards generally pose a risk of damage, loss, or harm to people and/or their property

Washington State Floodplain Management Law

Washington's floodplain management law (RCW 86.16, implemented through WAC 173-158) states that prevention of flood damage is a matter of statewide public concern and places regulatory control with the Department of Ecology. RCW 86.16 is cited in floodplain management literature, including FEMA's national assessment, as one of the first and strongest in the nation. A major challenge to the law in 1978, Maple Leaf Investors v. Ecology, is cited in legal references to floodplain management issues. The court upheld the law, declaring that denial of a permit to build residential structures in the floodway is a valid exercise of police power and did not constitute a taking. RCW Chapter 86.12 (Flood Control by Counties) authorizes county governments to levy taxes, condemn properties and undertake flood control activities directed toward a public purpose.

Flood Control Assistance Account Program

Washington's first flood control maintenance program was passed in 1951, and was called the Flood Control Maintenance Program. In 1984, RCW 86.26 (State Participation in Flood Control Maintenance)

established the Flood Control Assistance Account Program (FCAAP), which provides funding for local flood hazard management. FCAAP rules are found in WAC 173-145. Ecology distributes FCAAP matching grants to cities, counties and other special districts responsible for flood control. This is one of the few state programs in the U.S. that provides grant funding to local governments for floodplain management. The program has been funded for $4 million per Biennium since its establishment, with additional amounts provided after severe flooding events.

To be eligible for FCAAP assistance, flood hazard management activities must be approved by Ecology in consultation with the Washington Department of Fish and Wildlife. A comprehensive flood hazard management plan must have been completed and adopted by the appropriate local authority or be in the process of being prepared in order to receive FCAAP flood damage reduction project funds. This policy evolved through years of the Flood Control Maintenance Program and early years of FCAAP in response to the observation that poor management in one part of a watershed may cause flooding problems in another part.

Local jurisdictions must participate in the NFIP and be a member in good standing to qualify for an FCAAP grant. Grants up to 75 percent of total project cost are available for comprehensive flood hazard management planning. Flood damage reduction projects can receive grants up to 50 percent of total project cost, and must be consistent with the comprehensive flood hazard management plan. Emergency grants are available to respond to unusual flood conditions. FCAAP can also be used for the purchase of flood prone properties, for limited flood mapping and for flood warning systems. Funding currently is running about 60 percent for planning and 40 percent for projects.

6.10.3 Local Programs

Each planning partner has prepared a jurisdiction-specific annex to this plan (see Volume 2). In preparing these annexes, each partner completed a capability assessment that looked at its regulatory, technical and financial capability to carry out proactive hazard mitigation. Refer to these annexes for a review of regulatory codes and ordinances applicable to each planning partner. This section provides an overview of programs in King County that can support or enhance the initiatives identified in this plan.

King County Flood Control District

The King County Flood Control District (District) is an independent special purpose district established by King County Council Ordinance 15728. State law authorizes King County Council members to be the members of the Board of Supervisors that is the district’s governing body. The Board of Supervisors oversees the district’s funding, projects, policies and programs. The District Advisory Committee provides the Board of Supervisors with policy recommendations on regional flood protection and annual budgeting issues and on priorities and implementation strategies for the district’s capital improvement program.

Staff from the River and Floodplain Management Section of King County’s Department of Natural Resources and Parks (Water and Land Resources Division) are responsible, under an inter-local agreement between the County and the District, for developing and implementing board-approved flood protection projects and programs.

Basin Technical Committees for each major river basin (Snoqualmie/South Fork Skykomish Rivers, Cedar/Sammamish Rivers, Green/Duwamish River and White River) ensure that basin-scale issues and basin-specific technical information are considered in regional decision-making. Committee members are staff from local governments in each basin, along with District staff. Tribal governments also are invited to participate. Together, basin committee members coordinate with state and federal partners, review and guide flood hazard management projects and share information on relevant flood issues. They provide

technical advice and recommendations to the district's Advisory Committee, which in turn makes recommendations to the District's Board of Supervisors. Figure 6 -23 illustrates the District's overall governance structure.

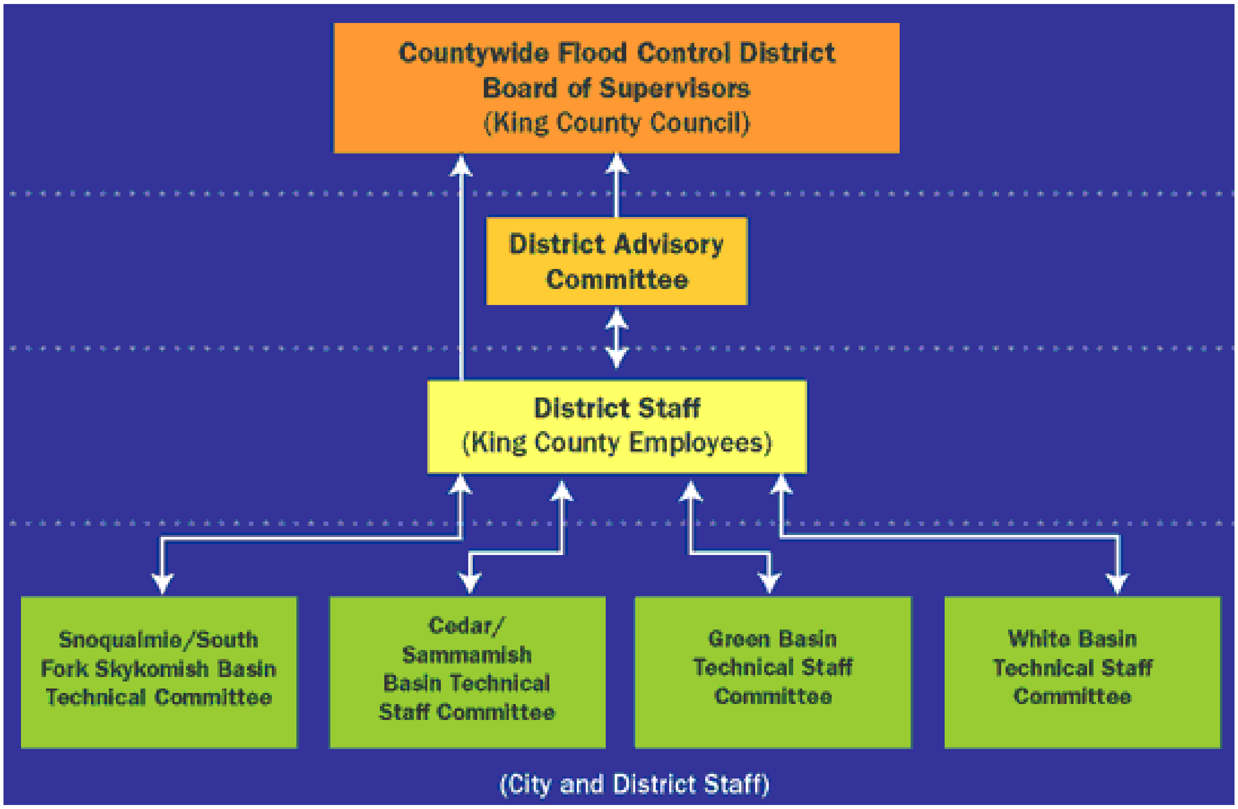


Figure 6-23. King County Flood Control District Governance Structure

The Resilient King County Initiative

In 2013, King County convened a group of leaders from the corporate and nonprofit sectors to build a comprehensive strategy for how King County will recover from a major catastrophe. The group's meeting launched the Resilient King County initiative, based on King County's Regional Capabilities Assessment, the Resilient Washington State initiative, and the National Disaster Recovery Framework. The Resilient King County initiative seeks to establish a framework to assist individuals, families, businesses and government in rebuilding the community after a disaster in a way that sustains its physical, emotional, social, and economic well-being. It defines a resilient King County as follows:

> A resilient King County has the capacity to maintain the services and livelihoods that its residents rely on after a catastrophic hazard event. In the event that these services and livelihoods are disrupted, recovery within King County occurs in a systematic, defensible, and transparent manner that balances speed and opportunity.

The purpose of the Resilient King County initiative is to obtain insights and feedback from stakeholders in King County to further the development of King County's Regional Long-Term Recovery Plan. The insights and feedback will be synthesized into a report that establishes a framework for conducting tradeoffs before and during the recovery process in coordination with other King County jurisdictions and key stakeholders.

King County Strategic Plan 2010-2014

The King County Council adopted the *King County Strategic Plan, 2010–2014: Working Together for One King County*. The plan, created with input from residents and county employees in collaboration with the county's elected officials, is a key tool in work to reform county government by focusing on customer service, partnerships and ways to bring down the cost of government.

CLIMATE CHANGE CONSIDERATIONS FOR HAZARD MITIGATION

7.1 WHAT IS CLIMATE CHANGE?

Climate, consisting of patterns of temperature, precipitation, humidity, wind and seasons, plays a fundamental role in shaping natural ecosystems and the human economies and cultures that depend on them. “Climate change” refers to changes over a long period of time. Worldwide, average temperatures have increased more than 1.4ºF over the last 100 years (NRC, 2010). Although this change may seem small, it can lead to large changes in climate and weather.

The warming trend and its related impacts are caused by increasing concentrations of carbon dioxide and other greenhouse gases in the earth’s atmosphere. Greenhouse gases are gases that trap heat in the atmosphere, resulting in a warming effect. Carbon dioxide is the most commonly known greenhouse gas; however, methane, nitrous oxide and fluorinated gases also contribute to warming. Emissions of these gases come from a variety of sources, such as the combustion of fossil fuels, agricultural production and changes in land use. According to the U.S. Environmental Protection Agency (EPA), carbon dioxide concentrations measured about 280 parts per million (ppm) before the industrial era began in the late 1700s and have risen 41 percent since then, reaching 394 ppm in 2012 (see Figure 7 -24). The EPA attributes almost all of this increase to human activities (U.S. EPA, 2013f).

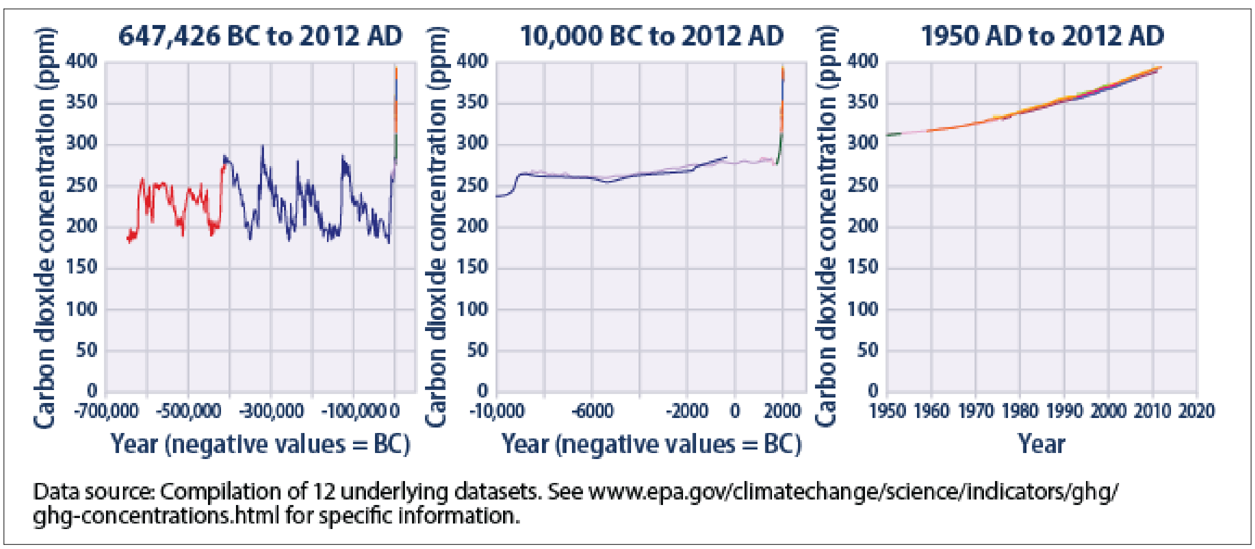


Figure 7-24. Global Carbon Dioxide Concentrations Over Time

Climate change will affect the people, property, economy and ecosystems of King County in a variety of ways. Some impacts will have negative consequences for the region and others may present opportunities. The most important effect for the development of this plan is that climate change will have a measurable impact on the occurrence and severity of natural hazards.

7.2 HOW CLIMATE CHANGE AFFECTS HAZARD MITIGATION

An essential aspect of hazard mitigation is predicting the likelihood of hazard events in a planning area. Typically, predictions are based on statistical projections from records of past events. This approach assumes that the likelihood of hazard events remains essentially unchanged over time. Thus, averages based on the past frequencies of, for example, floods are used to estimate future frequencies: if a river has flooded an average of once every five years for the past 100 years, then it can be expected to continue to flood an average of once every five years.

For hazards that are affected by climate conditions, the assumption that future behavior will be equivalent to past behavior is not valid if climate conditions are changing. As flooding is generally associated with precipitation frequency and quantity, for example, the frequency of flooding will not remain constant if broad precipitation patterns change over time. The risks of avalanche, landslide, severe weather, severe winter weather and wildfire are all affected by climate patterns as well.

For this reason, an understanding of climate change is pertinent to efforts to mitigate natural hazards. Information about how climate patterns are changing provides insight on the reliability of future hazard projections used in mitigation analysis. This chapter summarizes current understandings about climate change in order to provide a context for the recommendation and implementation of hazard mitigation measures in King County.

7.3 CURRENT INDICATIONS OF CLIMATE CHANGE

7.3.1 Global Indicators

The major scientific agencies of the United States—including the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA)—agree that climate change is occurring (U.S. EPA, 2013). Multiple temperature records from all over the world have shown a warming trend (U.S. EPA, 2011). According to NOAA, the decade from 2000 to 2010 was the warmest on record, and 2010 was tied with 2005 as the warmest year on record (NOAA, 2011). Worldwide, average temperatures have increased more than 1.4ºF over the last 100 years (NRC, 2010). Many of the extreme precipitation and heat events of recent years are consistent with projections based on that amount of warming (USGCRP, 2009).

Rising global temperatures have been accompanied by other changes in weather and climate. Many places have experienced changes in rainfall resulting in more intense rain, as well as more frequent and severe heat waves. The planet's oceans and glaciers have also experienced changes: oceans are warming and becoming more acidic, ice caps are melting, and sea levels are rising (U.S. EPA, 2010). Global sea level has risen approximately 9 inches, on average, in the last 140 years (U.S. EPA, 2010). This has already put some coastal homes, beaches, roads, bridges, and wildlife at risk (USGCRP, 2009).

7.3.2 Indicators Tracked by King County

Environmental changes such as increasing air and water temperatures, acidifying marine waters, increasing fall flooding, rising sea levels, decreasing snow pack, and decreasing summertime river flow have already been documented within King County (King County, 2013a). The County has been tracking a series of indicators that will provide information about local climate change impacts and help assess their severity. The County is also tracking greenhouse gas emissions for all King County residents, businesses and government operations and preparing for climate change impacts. The indicators that King County has been tracking demonstrate the following impacts to date (King County, 2013a):

- **Stream temperatures**—During the period 2000-2011, the moving 7-day average of the daily maximum temperatures for the majority of the 63 stream and river sites in King County exceeded the 16°C temperature standard established for the protection of salmon habitat.
- **Large lake temperatures**—The trend in annual average lake temperatures, including Lake Washington and Lake Sammamish, is toward higher average water temperatures.
- **Summer Stream Flows—**Trend analysis of long-term King County river discharge records (1962-2008) in nine unregulated rivers and the naturalized flow record for the Green River at Howard Hanson Dam provide strong evidence of declining summer flow (July - September) and some evidence that severe storms and floods occur more frequently in late fall.
- **Rainfall**—Annual precipitation in the Pacific Northwest region increased 14 percent from 1930 through 1995. There is some evidence from local weather and gauging river stations that severe storms and floods are occurring more frequently. A local study indicated a general trend toward higher precipitation in November and lower precipitation during summer. In addition, results suggest increases in the magnitude, duration, frequency, and earlier timing of extreme precipitation.
- **Sea level rise**—Oceans rose approximately 8 inches from 1870 to 2008, an average of 0.06 inches per year. Recent years have shown an increase in the rate of change. At a station in Seattle, the trend of monthly mean sea level (1898 to 2006) is 2.06 mm/year (equivalent to a change of 0.68 feet in 100 years).
- **Air temperature**—In the Pacific Northwest, average annual temperatures rose 1.5°F in the last century.
- **Snowpack**—Widespread declines in spring snowpack have occurred in much of the North American west between 1925 and 2000. Between about mid-century and 2006, decreases of about 15 to 35 percent in snow water equivalent in the Cascades Mountains were observed.
- **Sea surface temperature**—Global sea surface temperatures increased over the 20th century at an average rate of 0.12°F per decade. Over the last 30 years, global surface temperatures have risen at a faster rate of change of 0.21°F per decade. Records from a station in Victoria, BC indicate a long-term warming trend of 1.7°F since 1921 and 1.8°F since 1950.
- **Ocean acidification**—Over the past 250 years, oceans have absorbed about 550 billion tons of carbon dioxide emissions, or about 30 percent of total carbon emissions created by human activity. Globally, ocean surface water pH is estimated to have fallen about 0.1 pH units since the beginning of the industrial revolution.
- **Human Health and Heat**—Data from the greater Seattle area indicate that between 1980 and 2006 the risk of death and mortality due to all non-traumatic causes and circulatory causes rose for citizens 45 years and older during the hottest summer days.
- **Air Quality**—The number of days per year with air particulates exceeding the Particulate Matter Size 2.5 daily health standard has been decreasing over the last 10 years—from about 60 days in 2000 down to fewer than 10 days in 2010.
- **County Operations**—Over the short period for which data is available (since 2007), data show a trend in increasing hours of operation of the King County Flood Warning Center.
- **FEMA disasters**—Flood, severe storm and coastal storm related FEMA disasters in King County have been occurring more frequently in the past decade.
- **Fish**—Wild juvenile chinook salmon abundance in King County watersheds has been decreasing since the early 2000s. Wild chinook salmon escapement results in 2010 were far below the recovery goals—at only 7 percent of the recovery target.

7.4 PROJECTED FUTURE IMPACTS

7.4.1 Global Projections

Scientists project that Earth's average temperatures will rise between 2ºF and 12ºF by 2100 (NRC, 2011a). Some research has concluded that every increase of 2ºF in average global average temperature can have the following impacts (NRC, 2011b):

- 3 to 10 percent increases in the amount of rain falling during the heaviest precipitation events, which can increase flooding risks
- 200 to 400 percent increases in the area burned by wildfire in parts of the western United States
- 5 to 10 percent decreases in stream flow in some river basins
- 5 to 15 percent reductions in the yields of crops as currently grown.

The amount of sea level rise expected to occur as a result of climate change will increase the risk of coastal flooding for millions to hundreds of millions of people around the world, many of whom would have to permanently leave their homes (IPCC, 2007). By 2100, sea level is expected to rise another 1.5 to 3 feet (NRC, 2011b). Rising seas will make coastal storms and the associated storm surges more frequent and destructive. What is currently termed a once-in-a-century coastal flooding event could occur as frequently as once per decade (USGCRP, 2009).

7.4.2 Projections for Washington State

The Climate Impacts Group at the University of Washington used multiple climate models to evaluate potential climate change in Washington State and the Pacific Northwest region. The following are key findings of that study that are relevant for hazard mitigation planning (Climate Impacts Group, 2009):

- Climate models project increases in annual temperature (compared to 1970 – 1999 and averaged across all models) of 2.0°F by the 2020s, 3.2°F by the 2040s, and 5.3°F by the 2080s.
- Projected changes in annual precipitation, averaged over all models, are small (+1 to +2 percent), but some models project an enhanced seasonal precipitation cycle with changes toward wetter autumns and winters and drier summers.
- Regional climate models generally predict increases in extreme high precipitation over the next half-century, particularly around Puget Sound.
- April 1 snowpack is projected to decrease (compared with the 1916 – 2006 historical average) by 28 percent across the state by the 2020s, 40 percent by the 2040s, and 59 percent by the 2080s.
- Due to increased summer temperature and decreased summer precipitation, the area burned by fire in the U.S. portion of the Columbia River basin is projected to double by the 2040s and triple by the 2080s. The probability that more than 2 million acres in that area will burn in a given year is projected to increase from 5 percent today to 33 percent by the 2080s.
- Projected warming would likely result in 101 additional deaths during heat events in the greater Seattle area among persons 45 and older in 2025 and 156 additional deaths in 2045.

- By mid-century, King County will likely experience 132 additional deaths annually between May and September due to worsened air quality caused by climate change.

7.5 RESPONSES TO CLIMATE CHANGE

7.5.1 Mitigation and Adaptation

Communities and governments worldwide are working to address, evaluate and prepare for climate changes that are likely to impact communities in coming decades. Generally, climate change discussions encompass two separate but inter-related considerations: mitigation and adaptation. The term “mitigation” can be confusing, because its meaning changes across disciplines:

- Mitigation in restoration ecology and related fields generally refers to policies, programs or actions that are intended to reduce or to offset the negative impacts of human activities on natural systems. Generally, mitigation can be understood as avoiding, minimizing, rectifying, reducing or eliminating, or compensating for known impacts (CEQ, 1978).
- Mitigation in climate change discussions is defined as “a human intervention to reduce the impact on the climate system.” It includes strategies to reduce greenhouse gas sources and emissions and enhance greenhouse gas sinks (U.S. EPA, 2013g).
- Mitigation in emergency management is typically defined as the effort to reduce loss of life and property by lessening the impact of disasters (FEMA, 2013).

In this chapter, mitigation is used as defined by the climate change community. In the other chapters of this plan, mitigation is primarily used in an emergency management context.

Adaptation refers to adjustments in natural or human systems in response to the actual or anticipated effects of climate change and associated impacts. These adjustments may moderate harm or exploit beneficial opportunities (U.S. EPA, 2013g).

Mitigation and adaptation are related, as the world’s ability to reduce greenhouse gas emissions will affect the degree of adaptation that will be necessary. Some initiatives and actions can both reduce greenhouse gas emissions and support adaptation to likely future conditions.

Societies across the world are facing the need to adapt to changing conditions associated with natural disasters and climate change. Farmers are altering crops and agricultural methods to deal with changing rainfall and rising temperature; architects and engineers are redesigning buildings; planners are looking at managing water supplies to deal with droughts or flooding.

Most ecosystems show a remarkable ability to adapt to change and to buffer surrounding areas from the impacts of change. Forests can bind soils and hold large volumes of water during times of plenty, releasing it through the year; floodplains can absorb vast volumes of water during peak flows; coastal ecosystems can hold out against storms, attenuating waves and reducing erosion. Other ecosystem services—such as food provision, timber, materials, medicines and recreation—can provide a buffer to societies in the face of changing conditions.

Ecosystem-based adaptation is the use of biodiversity and ecosystem services as part of an overall strategy to help people adapt to the adverse effects of climate change. This includes the sustainable management, conservation and restoration of specific ecosystems that provide key services.

7.5.2 Future Modeling Efforts

Current modeling efforts are unable to assess climate change at a resolution small enough to determine specific impacts for the individual communities of King County. However, generalized assessments of larger climatic regions can be used to determine impacts that are most likely to affect these communities.

Models are currently being developed to assess the potential impacts of climate change, but none are currently available to support hazard mitigation planning. As these models are developed in the future, the risk assessment presented in this plan may be enhanced to better measure these impacts.

7.5.3 Response To Climate Change in the Northwest

King County has been a national leader in working to address climate change. The County has engaged in the following planning strategies to address greenhouse gas emissions and the expected impacts that climate change will have on people, property, economy and ecosystems:

- The King County Global Warming Action Plan
- 2007 King County Climate Plan
- The 2012 King County Strategic Climate Action Plan
- Preparing for Climate Change Guidebook in conjunction with the University of Washington's Climate Impacts Group and Local Governments for Sustainability
- Participation in the Cities Climate Collaboration
- Mandating that greenhouse gas emission information be included in the environmental review process required by the State Environmental Policy Act.

King County government is not alone in the effort to address the sources and impacts of climate change. The State of Washington has adopted greenhouse gas reduction requirements that aim to reduce emissions to 1990 levels by 2020, to 25 percent below 1990 levels by 2035 and to 50 percent below 1990 levels by 2050 (RCW 47.01.440). Additionally, as of 2012, 17 of the 39 cities in the county are signatories to the U.S. Mayors' Climate Protection greenhouse gas emissions reduction target, which was launched by Seattle Mayor Greg Nickels in 2005.

2012 King County Strategic Climate Action Plan

The most recent County effort to address climate change is the 2012 King County Strategic Climate Action Plan which "synthesizes and focuses King County's most critical goals, objectives, strategies and priority actions to reduce greenhouse gas emissions and prepare for the effects of climate change" (King County, 2012). The Action Plan identifies goals for County operations and services in five areas that align with the King County Strategic Plan: transportation and land use; energy; forests and agriculture; consumption and materials management; and preparing for climate change impacts. Many of the actions identified in support of the goal of preparing for the likely impacts of climate change are directly related to the goals of hazard mitigation planning (King County, 2012):

- Manage flood risk.
- Educate and train the public and staff.
- Develop preparedness plans.
- Integrate climate change issues into emergency management.
- Plan for impacts on public health.
- Further develop reclaimed water program.

Cities Climate Collaboration

King County and the cities of Issaquah, Kirkland, Mercer Island, Redmond, Renton, Seattle, Shoreline, Snoqualmie and Tukwila have formed a partnership to "coordinate and enhance the effectiveness of local government climate and sustainability efforts." (King County, 2014) The effort focuses on developing and coordinating the following (King County, 2014):

- **Outreach**—Develop, refine and use messaging and tools for climate change outreach to engage decision makers, other cities and the general public.
- **Coordination**—Collaborate on adopting consistent standards, benchmarks, strategies and overall goal related to responding to climate change.
- **Solution**—Share local success stories, challenges, data and products that support and enhance The climate mitigation efforts by all partners.
- **Funding and resources**—Collaborate to secure grant funding and other shared resource opportunities to support climate related project and programs.

State Environmental Policy Act

In Washington State, development proposals that may have an adverse impact on the environment are subject to an environmental review that adheres to the requirements of the State Environmental Policy Act. King County was the first in the nation to take official action to add greenhouse gas emission considerations to the review of construction projects. According to the King County Sustainability Report, greenhouse gas emissions associated with development come from multiple sources:

- The extraction, processing, transportation, construction and disposal of building materials
- Landscape disturbance
- Energy demands created by the development after it is completed
- Transportation demands created by the development after it is completed.

The assessment required by the King County policy provides an estimate of all greenhouse gas emissions that will be created over the life of the building. This includes emissions associated with obtaining construction materials, fuel used during construction, energy consumed during the building's operation, and transportation by building occupants (King County, 2013b).

King County Comprehensive Plan

King County is involved in efforts to link climate change planning to local land use decisions. The King County Comprehensive Plan identifies polices that will help the County prepare for the impacts of climate change. According to the Adaptation section of the comprehensive plan, King County can increase resiliency and adapt to climate change through actions such as the following (King County Department of Permitting and Environmental Review, 2013):

- Coordinated public health and disaster planning
- Climate-sensitive land use planning
- Investments in flood hazard management projects
- Collaborative planning with water suppliers and development of reclaimed water sources
- Comprehensive approaches to conserving biodiversity that may make habitats more resilient to climate change impacts

- Information sharing and collaboration with other local governments developing strategies for climate change adaptation
- Cooperation with farm and forest landowners to identify and address impacts of climate change
- Siting facilities and using sustainable building practices to reduce vulnerability to the impacts of climate change.

The Comprehensive Plan identifies the following examples of County efforts to implement and learn from practical preparedness steps:

- Analyzing and planning for sea level rise impacts on Vashon Island and wastewater and road infrastructure
- Assessing and reducing flood impacts in partnership with the King County Flood Control District
- Developing reclaimed water systems and markets.

In general, actions throughout the planning area that promote the reduction of greenhouse gas emissions from all sectors support both hazard mitigation and climate change objectives. These actions include reducing fossil fuel consumption through transit initiatives, implementing green building and infrastructure design, protecting and enhancing the provision of ecosystem services, and assessing emissions from local government purchasing and operating protocols.

7.6 POTENTIAL CLIMATE CHANGE IMPACT ON HAZARDS

Although no modeling is currently available to develop quantitative estimates of the effect of climate change on natural hazard risks, an understanding of the basic features of climate change allows for the following qualitative assessments of impacts on hazards of concern addressed in this hazard mitigation plan. This overview serves as a basis for evaluating how risk will change as a result of future climate change impacts. The vulnerabilities identified in this plan update will ultimately be used to inform other aspects of emergency management planning, such as the Comprehensive Emergency Management Plan.

7.6.1 Avalanche

Snow avalanches are rarely used as indicators of climate change. The effects of climate change on avalanche frequency and magnitude are uncertain and will likely be dependent on local climate change impacts, such as changes in snowfall events and temperature series. Some studies have indicated that the types of avalanche events (wet or dry) may shift as a result of changes in snow cover (Martin et al., 2001). Avalanches, however, are not influenced by snow cover alone, but by several interrelated factors including forest structure, surface energy balance, melt water routing, precipitation, air temperature and wind (Teich et al., 2012; Lazar and Williams, 2008).

Secondary and tertiary impacts of climate change may also alter avalanche events. For example, climate change may modify the distribution of tree species across mountain landscapes. Some case studies in the Swiss and French Alps indicate that climate change impacts may reduce the frequency or severity of such events, while other assessments indicate that events may occur more frequently in other mountain regions (Kohler, 2009; Teich et al. 2012). No studies assessing the relative frequency and severity of avalanches in the Cascade Range were located, but an analysis of wet avalanche hazards in an Aspen ski area indicated that such effects may occur more frequently under high-emission scenarios (Lazar and Williams, 2008). Feedback loops affecting snow cover, forest structure, meteorological averages, and land use planning decisions are all likely to influence the future frequency and severity of impacts from avalanche events.

7.6.2 Dam Failure

Dams are designed partly based on assumptions about a river's flow behavior, expressed as hydrographs. Changes in weather patterns can have significant effects on the hydrograph used for the design of a dam. If the hygrograph changes, it is conceivable that the dam can lose some or all of its designed margin of safety, also known as freeboard. If freeboard is reduced, dam operators may be forced to release increased volumes earlier in a storm cycle in order to maintain the required margins of safety. Such early releases of increased volumes can increase flood potential downstream. Throughout the west, communities downstream of dams are already experiencing increases in stream flows from earlier releases from dams.

Dams are constructed with safety features known as "spillways." Spillways are put in place on dams as a safety measure in the event of the reservoir filling too quickly. Spillway overflow events, often referred to as "design failures," result in increased discharges downstream and increased flooding potential. Although climate change will not increase the probability of catastrophic dam failure, it may increase the probability of design failures.

7.6.3 Earthquake

The impacts of global climate change on earthquake probability are unknown. Some scientists say that melting glaciers could induce tectonic activity. As ice melts and water runs off, tremendous amounts of weight are shifted on the earth's crust. As newly freed crust returns to its original, pre-glacier shape, it could cause seismic plates to slip and stimulate volcanic activity, according to research into prehistoric earthquakes and volcanic activity. NASA and USGS scientists found that retreating glaciers in southern Alaska may be opening the way for future earthquakes (NASA, 2004).

Secondary impacts of earthquakes could be magnified by climate change. Soils saturated by repetitive storms could experience liquefaction or an increased propensity for slides during seismic activity due to the increased saturation. Dams storing increased volumes of water due to changes in the hydrograph could fail during seismic events. There are currently no models available to estimate these impacts.

7.6.4 Flood

According to University of Washington scientists, global climate changes resulting in warmer, wetter winters are projected to increase flooding frequency in most Western Washington river basins. Future floods are expected to exceed the capacity and protective abilities of existing flood protection facilities, threatening lives, property, major transportation corridors, communities and regional economic centers.

Changes in Hydrology

Use of historical hydrologic data has long been the standard of practice for designing and operating water supply and flood protection projects. For example, historical data are used for flood forecasting models and to forecast snowmelt runoff for water supply. This method of forecasting assumes that the climate of the future will be similar to that of the period of historical record. However, the hydrologic record cannot be used to predict changes in frequency and severity of extreme climate events such as floods. Going forward, model calibration or statistical relation development must happen more frequently, new forecast-based tools must be developed, and a standard of practice that explicitly considers climate change must be adopted. Climate change is already impacting water resources, and resource managers have observed the following:

- Historical hydrologic patterns can no longer be solely relied upon to forecast the water future.
- Precipitation and runoff patterns are changing, increasing the uncertainty for water supply and quality, flood management and ecosystem functions.

- Extreme climatic events will become more frequent, necessitating improvement in flood protection, drought preparedness and emergency response.

The amount of snow is critical for water supply and environmental needs, but so is the timing of snowmelt runoff into rivers and streams. Rising snowlines caused by climate change will allow more mountain area to contribute to peak storm runoff. High frequency flood events (e.g. 10-year floods) in particular will likely increase with a changing climate. Along with reductions in the amount of the snowpack and accelerated snowmelt, scientists project greater storm intensity, resulting in more direct runoff and flooding. Changes in watershed vegetation and soil moisture conditions will likewise change runoff and recharge patterns. As stream flows and velocities change, erosion patterns will also change, altering channel shapes and depths, possibly increasing sedimentation behind dams, and affecting habitat and water quality. With potential increases in the frequency and intensity of wildfires due to climate change, there is potential for more floods following fire, which increase sediment loads and water quality impacts.

As hydrology changes, what is currently considered a 100-year flood may strike more often, leaving many communities at greater risk. Planners will need to factor a new level of safety into the design, operation, and regulation of flood protection facilities such as dams, bypass channels and levees, as well as the design of local sewers and storm drains.

Sea Level Rise

Sea level and temperature are interrelated (U.S. EPA, 2013e). Warmer temperatures result in the melting of glaciers and ice sheets. This melting means that less water is stored on land and, thus, there is a greater volume of water in the oceans. Water also expands as it warms, and the heat content of the world’s oceans has been increasing over the last several decades. According to the EPA, there is likely to be 13 inches of sea level rise in the Puget Sound basin by 2100. According to the Washington State Department of Ecology the impacts of sea level rise could include the following: increased coastal community flooding, coastal erosion and landslides, seawater well intrusion, and lost wetlands and estuaries.

7.6.5 Landslide

Climate change may impact storm patterns, increasing the probability of more frequent, intense storms with varying duration. Increase in global temperature could affect the snowpack and its ability to hold and store water. Warming temperatures also could increase the occurrence and duration of droughts, which would increase the probability of wildfire, reducing the vegetation that helps to support steep slopes. All of these factors would increase the probability for landslide occurrences.

7.6.6 Severe Weather

Climate change presents a challenge for risk management associated with severe weather. The frequency of severe weather events has increased steadily over the last century. The number of weather-related disasters during the 1990s was four times that of the 1950s, and cost 14 times as much in economic losses. Historical data shows that the probability for severe weather events increases in a warmer climate (see Figure 7 -25). According to the EPA, “Since 1901, the average surface temperature across the contiguous 48 states has risen at an average rate of 0.14°F per decade. Average temperatures have risen more quickly since the late 1970s (0.36 to 0.55°F per decade). Seven of the top 10 warmest years on record for the contiguous 48 states have occurred since 1998, and 2012 was the warmest year on record (U.S. EPA, 2013b).” This increase in average surface temperatures can also lead to more intense heat waves that can be exacerbated in urbanized areas by what is known as urban heat island effect. Additionally, the changing hydrograph caused by climate change could have a significant impact on the

intensity, duration and frequency of storm events. All of these impacts could have significant economic consequences.

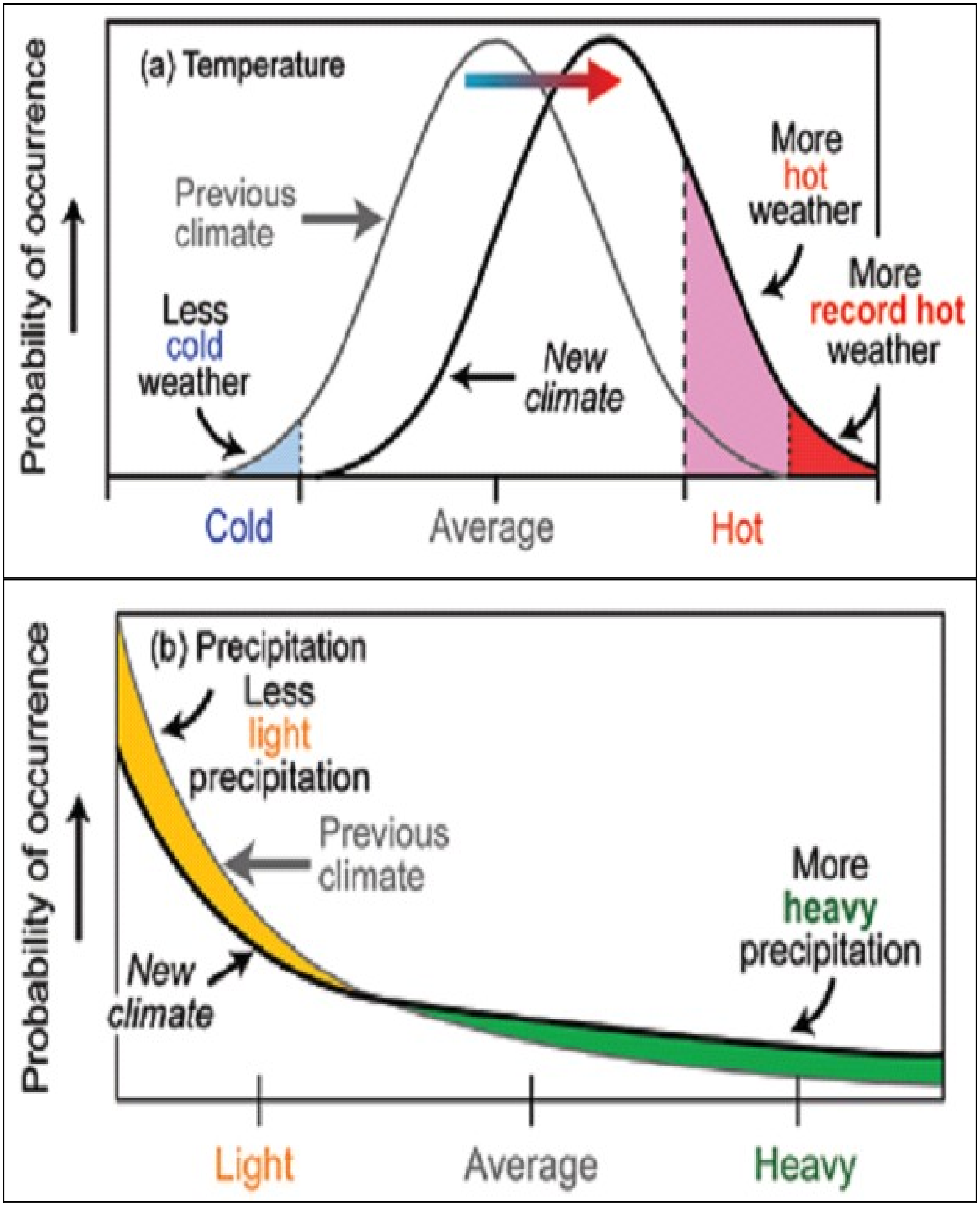


Figure 7-25. Severe Weather Probabilities in Warmer Climates

7.6.7 Severe Winter Weather

One impact of climate change is an increase in average ambient temperatures. Since the 1980s, unusually cold temperatures have become less common in the contiguous 48 states (U.S. EPA, 2013c). This trend is expected to continue and the frequency of winter cold spells will likely decrease.

As ambient temperatures increase, more water evaporates from land and water sources. The timing, frequency, duration and type of precipitation events will be affected by these changes. In general, more precipitation will fall as rain rather than snow; however, the amount of snowfall may increase where temperatures remain below freezing (U.S. EPA, 2013d). Snowfall may also change if typical storm track patterns are altered. Snowfall is already changing in the United States. According to the EPA (see Figure 7 -26; U.S. EPA, 2013d):

- Total snowfall has decreased in most parts of the country since widespread observations became available in 1930, with 57 percent of stations showing a decline.
- More than three-fourths of the stations across the contiguous 48 states have experienced a decrease in the proportion of precipitation falling as snow.
- Snowfall trends vary by region. The Pacific Northwest has seen a decline in both total snowfall and the proportion of precipitation falling as snow.

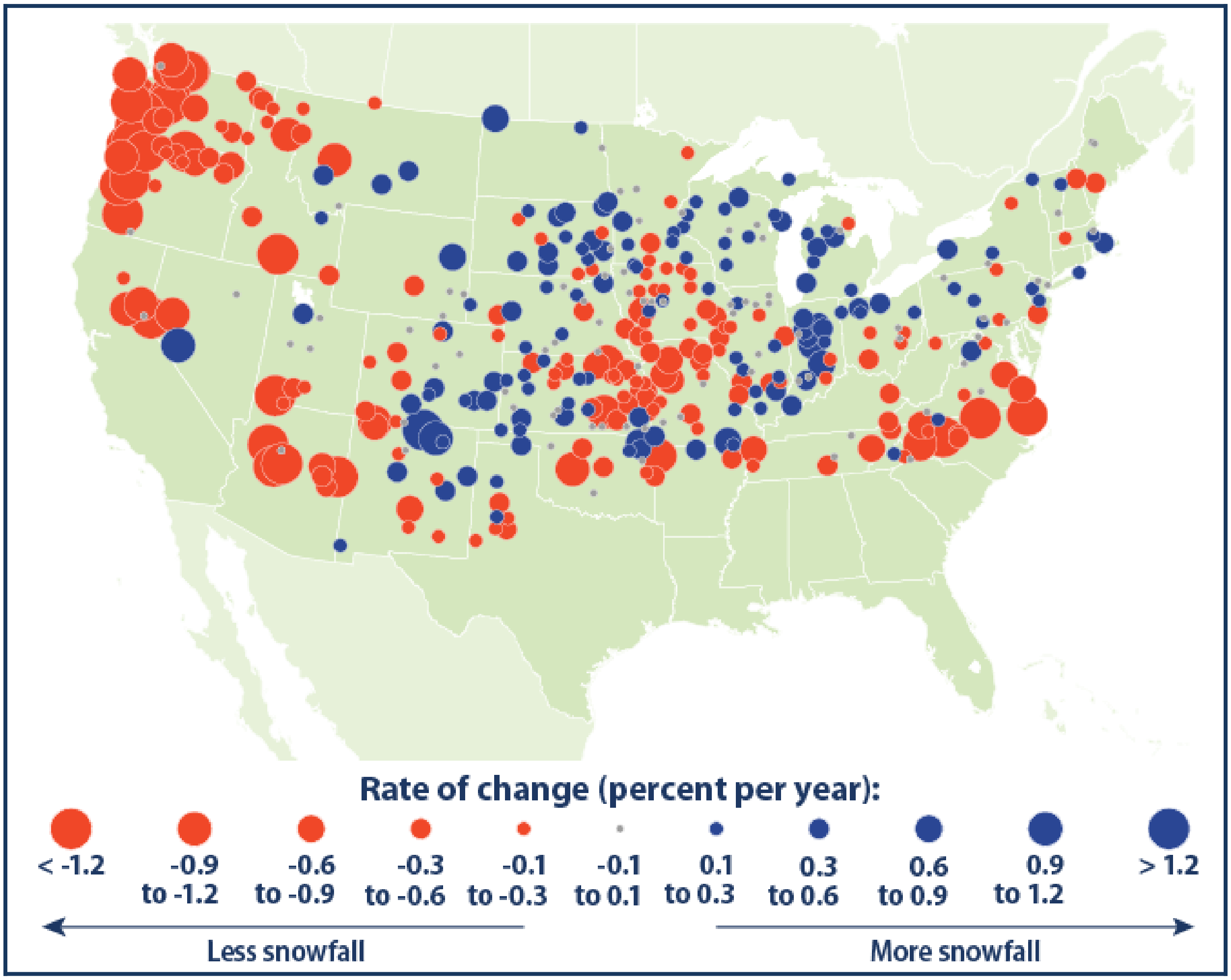


Figure 7-26. Change in snowfall, 1930-2007

From 1950 to 2000, snowpack has declined in most of the western United States, compared to historical averages. Western Washington, western Oregon and northern California have seen the greatest declines (U.S. EPA, 2013d). These changes will impact ecosystems, recreation opportunities, the hydroelectric power supply, and drinking water systems. The timing and magnitude of flooding may also be impacted by changes in the region's hydrograph, due to a greater percentage of precipitation falling as rain and earlier spring melt times.

7.6.8 Tsunami

The impacts of climate change on the frequency and severity of tsunami events could be significant in regions with vulnerable coastline. Global sea-level rise will affect all coastal societies, especially densely populated low-lying coastal areas. Sea level rise has two effects on low-lying coastal regions: any structures located below the new level of the sea will be flooded; and the rise in sea level may lead to coastal erosion that can further threaten coastal structures.

7.6.9 Volcano

Climate change is not likely to affect the risk associated with volcanoes; however, volcanic activity can affect climate change. Volcanic clouds absorb terrestrial radiation and scatter a significant amount of incoming solar radiation. By reducing the amount of solar radiation reaching the Earth's surface, large-scale volcanic eruptions can lower temperatures in the lower atmosphere and change atmospheric circulation patterns. The massive outpouring of gases and ash can influence climate patterns for years following a volcanic eruption.

7.6.10 Wildfire

Climate change has the potential to affect multiple elements of the wildfire system: fire behavior, ignitions, fire management, and vegetation fuels. Hot dry spells create the highest fire risk. Increased temperatures may intensify wildfire danger by warming and drying out vegetation. Climate change also may increase winds that spread fires. Forest response to increased atmospheric carbon dioxide could contribute to more tree growth and thus more fuel for fires, although the effects of carbon dioxide on mature forests are still largely unknown. In turn, increased high-elevation wildfires could release stores of carbon and further contribute to the buildup of greenhouse gases.

Wildfire in western ecosystems is determined by climate variability, local topography, and human intervention. Climate change has the potential to affect multiple elements of the wildfire system: fire behavior, ignitions, fire management, and vegetation fuels. Hot dry spells create the highest fire risk. Increased temperatures may intensify wildfire danger by warming and drying out vegetation. When climate alters fuel loads and fuel moisture, forest susceptibility to wildfires changes. Climate change also may increase winds that spread fires. Faster fires are harder to contain, and thus are more likely to expand into residential neighborhoods.

Historically, drought patterns in the West are related to large-scale climate patterns in the Pacific and Atlantic oceans. The El Niño–Southern Oscillation in the Pacific varies on a 5- to 7-year cycle, the Pacific Decadal Oscillation varies on a 20- to 30-year cycle, and the Atlantic Multidecadal Oscillation varies on a 65- to 80-year cycle. As these large-scale ocean climate patterns vary in relation to each other, drought conditions in the U.S. shift from region to region. El Niño years bring drier conditions to the Pacific Northwest and more fires.

Climate scenarios project summer temperature increases between 2ºC and 5°C and precipitation decreases of up to 15 percent. Such conditions would exacerbate summer drought and further promote high-elevation wildfires, releasing stores of carbon and further contributing to the buildup of greenhouse gases.

Forest response to increased atmospheric carbon dioxide could also contribute to more tree growth and thus more fuel for fires, but the effects of carbon dioxide on mature forests are still largely unknown. High carbon dioxide levels should enhance tree recovery after fire and young forest regrowth, as long as sufficient nutrients and soil moisture are available, although the latter is in question for many parts of the western United States because of climate change.

CHAPTER 8.

AVALANCHE

8.1 GENERAL BACKGROUND

Avalanches can occur whenever a sufficient depth of snow is deposited on slopes steeper than about 20 degrees, with the most dangerous coming from slopes in the 35- to 40-degree range. Avalanche-prone areas can be identified with some accuracy, since they typically follow the same paths year after year, leaving scarring on the paths. However, unusual weather conditions can produce new paths or cause avalanches to extend beyond their normal paths.

Common factors contributing to the avalanche hazard are old snow depth, old snow surface, new snow depth, new snow type, snow density, snowfall intensity, precipitation intensity, settlement, wind direction and speed, temperature, and subsurface snow crystal structure.

In the spring, warming of the snowpack occurs from below (from the warmer ground) and above (from warm air, rain, etc.). Warming can be enhanced near rocks or trees that transfer heat to the snowpack. The effects of a snowpack becoming weak may be enhanced in steeper terrain where the snowpack is shallow, and over smooth rock faces that may focus meltwater and produce "glide cracks." Such slopes may fail during conditions that encourage melt.

Wind can affect the transfer of heat into the snowpack and associated melt rates of near-surface snow. During moderate to strong winds, the moistening near-surface air in contact with the snow is constantly mixed with drier air above through turbulence. As a result, the air is continually drying out, which enhances evaporation from the snow surface rather than melt. Heat loss from the snow necessary to drive the evaporation process cools off near-surface snow and results in substantially less melt than otherwise might occur, even if temperatures are well above freezing.

When the snow surface becomes uneven in spring, air flow favors evaporation at the peaks, while calmer air in the valleys favors condensation there. Once the snow surface is wet, its ability to reflect solar energy drops dramatically; this becomes a self-perpetuating process, so that the valleys deepen (favoring calmer air and more heat transfer), while more evaporation occurs near the peaks, increasing the differential between peaks and valleys. However, a warm wet storm can quickly flatten the peaks as their larger surface area exposed to warm air, rain or condensation hastens their melt over the sheltered valleys.

DEFINITIONS

Avalanche—Any mass of loosened snow or ice and/or earth that suddenly and rapidly breaks loose from a snowfield and slides down a mountain slope, often growing and accumulating additional material as it descends.

Slab avalanches—The most dangerous type of avalanche, occurring when a layer of coherent snow ruptures over a large area of a mountainside as a single mass. Like other avalanches, slab avalanches can be triggered by the wind, by vibration, or even by a loud noise, and will pull in surrounding rock, debris and even trees.

Climax avalanches—An avalanche involving multiple layers of snow,.

Loose snow avalanches—An avalanche that occurs when loose, dry snow on a slope becomes unstable and slides. Loose snow avalanches start from a point and gather more snow as they descend, fanning out to fill the topography.

Powder snow avalanches—An avalanche that occurs when sliding snow has been pulverized into powder, either by rapid motion of low-density snow or by vigorous movement over rugged terrain.

Surface avalanches—An avalanche that occurs only in the uppermost snow layers.

Wet snow avalanche—An avalanche in wet snow, also referred to as a wet loose avalanche or a wet slab avalanche. Often the basal shear zone is a water-saturated layer that overlies an ice zone.

8.2 HAZARD PROFILE

8.2.1 Past Events

Avalanches in Washington have killed over 107 people since 1950, including 35 between 2003 and 2013 (CAIC, 2014). Records of large avalanches with loss of life or serious damage to property in or near the planning area include the following (Washington Emergency Management Division 2010, King County 2009 and Northwest Avalanche Center 2014):

- 1910 Stevens Pass—96 fatalities, 2 trains derailed
- 1971 Snoqualmie Pass—1 fatality
- 1996 Mount Index—3 fatalities
- 1996 – 1997 Snoqualmie Pass—hundreds of holiday travelers stranded
- 2001 Steven's Pass—2 fatalities
- 2002 Snoqualmie Pass—I-90 road closures lasting several days
- 2003 Alpental—1 fatality
- 2003 Snoqualmie Pass—1 fatality
- 2005 Alpental—1 fatality
- 2007 Snoqualmie Pass—2 fatalities
- 2012 Tunnel Creek—3 fatalities
- 2013 Snoqualmie Pass—2 fatalities in one day from 2 separate events

Avalanches also regularly close small access roads at higher elevations.

8.2.2 Location

The Cascade Range in the eastern half of King County receives extensive precipitation due to its size and orientation to the flow of Pacific marine air. In the local maritime climate, it is common for air temperatures to rise above freezing and for precipitation to change from snow to rain during mid-winter storm cycles. Temperatures can change several degrees within minutes, causing abrupt changes in precipitation type. These conditions frequently cause the release of avalanches. Figure 8 -27 shows avalanche hazard areas in Washington, including the easternmost portion of King County.

8.2.3 Frequency

At lower elevations of the Cascades, the avalanche season begins in November and continues until the last remnants of snow have melted in early summer. In the high alpine regions, the hazard continues year-round. Hundreds of thousands of avalanches are thought to occur each year in the Cascades.

8.2.4 Severity

Large external lateral loads can cause significant damage to structures and fatalities. Table 8 -16 indicates the estimated potential damage for a given range of impact pressures.

There may be an impact on the planning area's economy as a result of the avalanche hazard. The timber industry, power companies, recreational resorts, homeowners and recreational groups depend on relatively free access to wildland areas that may be restricted during periods of high avalanche threat.

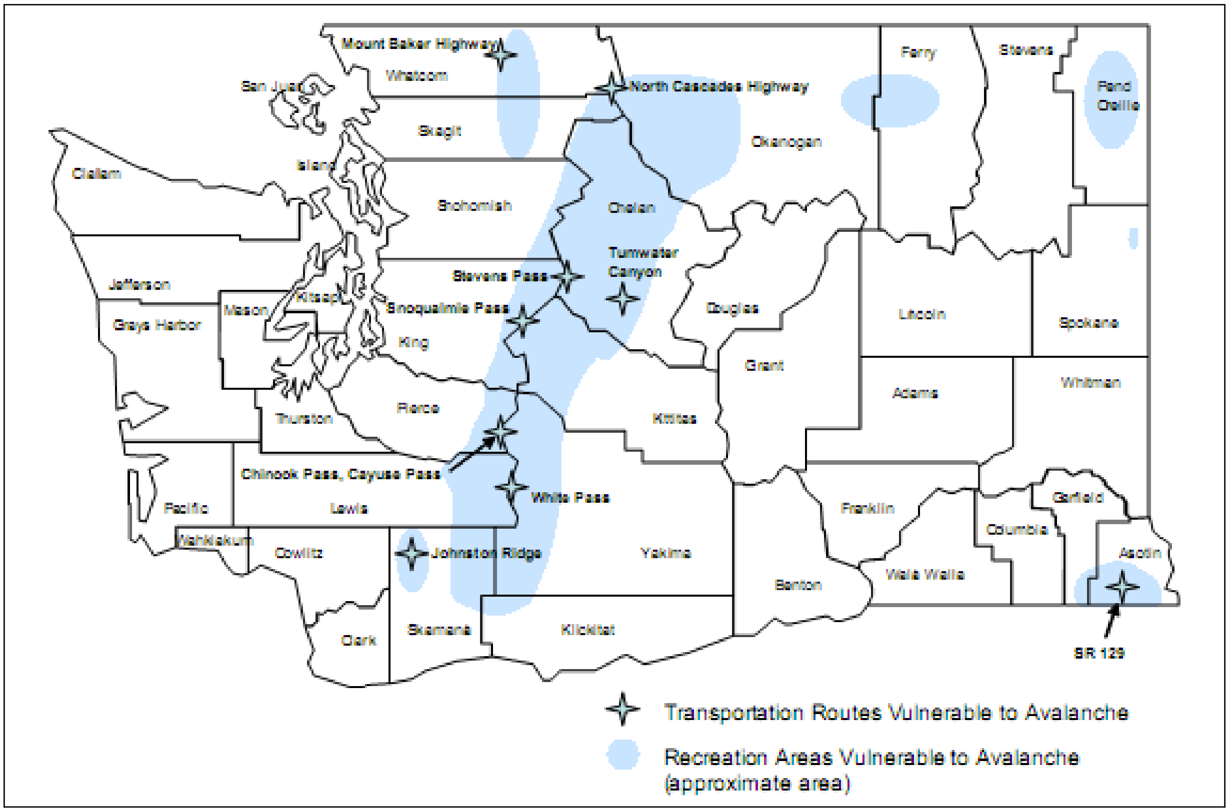


Figure 8-27. Areas Vulnerable to Avalanche

TABLE 8-16.
IMPACT PRESSURES RELATED TO DAMAGE

Impact Pressure (pounds per square foot)	Potential Damage
40-80	Break windows
60-100	Push in doors, damage walls, roofs
200	Severely damage wood frame structures
400-600	Destroy wood-frame structures, break trees
1,000-2,000	Destroy mature forests
>6,000	Move large boulders

Source: www.avalanche.org

Avalanche control is important along Interstate 90 through Snoqualmie Pass. I-90 is a heavily traveled corridor that connects major Puget Sound communities to Eastern Washington through the Cascade Mountains. Snoqualmie Pass is the state's only Interstate highway link through the Cascades. It averages nearly 450 inches of snow each winter and has a daily traffic volume of 32,000 vehicles (including 8,000 trucks). Economists estimate that the closing of Snoqualmie Pass has an economic cost to the state of $500,000 to $750,000 per hour (Washington State Emergency Management Division, 2010).

The BNSF Railway follows essentially the same east-west route as SR-2. The potential for rail service interruption, or for damage to a train carrying hazardous cargo in populated or environmentally sensitive areas, is of concern.

The following weather and terrain factors affect avalanche severity and danger:

- Storms—A large percentage of all snow avalanches occur during and shortly after storms.
- Rate of snowfall—Snow falling at a rate of 1 inch or more per hour rapidly increases avalanche danger.
- Temperature—Storms starting with low temperatures and dry snow, followed by rising temperatures and wetter snow, are more likely to cause avalanches than storms that start warm and then cool with snowfall.
- Wet snow—Rainstorms or spring weather with warm, moist winds and cloudy nights can warm the snow cover, resulting in wet snow avalanches. Wet snow avalanches are more likely on sun-exposed terrain (south-facing slopes) and under exposed rocks or cliffs.
- Ground cover—Large rocks, trees and heavy shrubs help anchor snow.
- Slope profile—Dangerous slab avalanches are more likely to occur on convex slopes.
- Slope aspect—Leeward slopes are dangerous because windblown snow adds depth and creates dense slabs. South-facing slopes are more dangerous in the springtime.
- Slope steepness—Snow avalanches are most common on slopes of 30 to 45 degrees.

8.2.5 Warning Time

The Northwest Weather and Avalanche Center provides daily forecasts as well as information regarding significantly increased avalanche danger that may serve as advanced warning for individuals participating in activities where avalanches may occur. These warning are generalized and simply alert exposed individuals to an increased risk of occurrence.

The time of an avalanche release depends on the condition of the snow pack; which can change rapidly during a day and particularly during rainfall. Research in the Cascade Mountains has shown that most natural avalanches occurred less than 1 hour after the onset of rain; in these cases the snow pack was initially weak (Washington Emergency Management Division, 1996). In cases where the snow pack was stronger, avalanche activity was delayed or did not occur. Nonetheless an avalanche can occur with little or no warning time, which makes them particularly deadly.

8.3 SECONDARY HAZARDS

Avalanches can cause blocked roads, which can isolate residents and businesses and delay commercial, public and private transportation. This could result in economic losses for businesses. Other potential problems resulting from avalanches are power and communication failures. Avalanches also can damage rivers or streams, potentially harming water quality, fisheries and spawning habitat.

8.4 EXPOSURE

There is minimal development in the high Cascade Range, which makes King County's exposure to an avalanche small. Most mountainous areas in the county are part of the Mount Baker-Snoqualmie National Forest and other protected forests. There is risk to the development and users that do exist. The only incorporated area near the avalanche hazard area is the Town of Skykomish; however impacts within the town limits are unlikely.

8.4.1 Population

There are no major populations exposed to avalanches in the county. Most of the avalanche hazard area is uninhabited or has minimal development. None of the ski resorts on King County's mountains are considered to be exposed to avalanches within their boundaries due to their ski slope maintenance protocols. Skiers who ski out of bounds in these areas are exposed to avalanches. People working in the mountains, such as miners and loggers, are exposed, as are recreational users, such as hikers and cross-country skiers. Travelers moving through avalanche-prone areas, especially Steven's Pass and Snoqualmie Pass, are also exposed.

8.4.2 Property

There is little property exposed to avalanches. Property and buildings exposed include National Forest huts and temporary structures belonging to mining and forestry operations.

8.4.3 Critical Facilities and Infrastructure

There are no critical facilities exposed to avalanches. There is a small amount of infrastructure that could be blocked by avalanches, including hiking trails, fire roads and logging roads. SR-2 above Index is exposed to avalanches, as are several stretches of Interstate 90. The BNSF Railway passes through the mountains and could be exposed.

8.4.4 Environment

Avalanches are a natural event, but they can negatively affect the environment. This includes trees located on steep slopes. A large avalanche can knock down many trees and kill the wildlife that lives in them. In spring, this loss of vegetation on the mountains may weaken the soil, causing landslides and mudflows.

8.5 VULNERABILITY

In general, everything that is exposed to an avalanche event is vulnerable. More and more people are working and building in or using the high mountain areas of the Cascades in potential avalanche areas. These individuals often have little experience with, caution regarding, or preparation for, avalanche conditions. The increasing development of recreational sites in the mountains brings added exposure to the people using these sites and the access routes to them. The risk to human life is especially great at times of the year when rapid warming follows heavy, wet snowfall.

Interstate 90 could be blocked by avalanches, but the Washington Department of Transportation conducts active winter avalanche control or mitigation on Interstate 90. This means avalanches are triggered intentionally on slopes above the roadways in a controlled environment to minimize traffic disruption and promote public safety. The Department of Transportation also conducts passive avalanche control by building elevated roadways so avalanches can pass under highways, snow sheds so that avalanching snow flows over highways, catchment basins to stop avalanche flow, and diversion dams and berms to keep snow off highways.

King County's transportation infrastructure is also vulnerable to avalanches. In most winters, snow slides can close any of the pass highways between western and eastern Washington. The avalanche threat was not a significant consideration in either the planning or construction of Washington's older mountain highways such as SR-2. Although costs associated with removing avalanches from SR-2 are borne by the state Department of Transportation, the County's road network and substantial commercial activity are also dependent upon the connectivity provided by this main highway.

8.6 FUTURE TRENDS IN DEVELOPMENT

Given the likely location and density of future development based on current land use regulations, there is a small amount of housing and employment capacity that has the potential to be developed in avalanche hazard areas. Most of the land area in the avalanche hazard zone is resource or protected land. As of 2005 there were approximately 5,700 existing housing units on resource lands in King County (King County, 2007). Not all of these housing units are located in the avalanche hazard area. It is estimated that about 4 percent of the county's growth will occur in rural and resource lands for the 2001-2022 planning period (King County, 2007). Based on the 2008 King County Annual Growth Report, only two new residential units were built in 2007 in possible avalanche hazard areas.

8.7 SCENARIO

In a worst-case scenario, an avalanche would occur in the Cascade Mountains after a series of storms. Storms starting with low temperatures and dry snow, followed by rising temperatures and wetter snow, are more likely to cause avalanches than storms that start warm and then cool with snowfall.

8.8 ISSUES

Avalanches pose a threat to recreational users and property and can disrupt the east-west transportation network. Specially trained Washington Department of Transportation avalanche-control teams use active and passive means to reduce the avalanche hazard near Snoqualmie and Stevens Pass each year. Their efforts limit the number and duration of highway closures. The state posts warning signs in key locations warning recreation users of avalanche dangers, although these signs are commonly ignored. There is no effective way to keep the public out of avalanche-prone recreational areas, even during times of highest risk. A coordinated effort is needed among state, county and local law enforcement, fire, emergency management and public works agencies and media to provide better avalanche risk information.

A national program to rate avalanche risk has been developed to standardize terminology and provide a common basis for recognizing and describing hazardous conditions. This United States Avalanche Danger Scale relates degree of avalanche danger (low, moderate, considerable, high, extreme) to descriptors of avalanche probability and triggering mechanism, degree and distribution of avalanche hazard, and recommended action in back country. Figure 8 -28 shows key elements of the danger scale. This information, updated daily, is available during avalanche season from the joint NOAA/U.S. Forest Service Northwest Weather and Avalanche Center and can be obtained from Internet, NOAA weather wire, and Department of Transportation sources. Avalanche danger scale information should be explained to the public and made available through appropriate county and local agencies and the media.

The state's maintains over 50 years of detailed records to help technicians forecast how snow might behave; however, climate change will likely alter the frequency and magnitude of avalanche events in the planning area. Methods will need to be developed to integrate forward-looking standards and best practices for avalanche management techniques.

The Northwest Weather and Avalanche Center provides a source of information to recreational users regarding current conditions and danger levels as well as incident summaries by date and location and additional resources. Measures that have been used in other jurisdictions to reduce avalanche threat include monitoring timber harvest practices in slide-prone areas to ensure that snow cover is stabilized as well as possible, and encouraging reforestation in areas near highways, buildings, power lines and other improvements. The development of a standard avalanche report form, and the maintenance of a database of potential avalanche hazards likely to affect proposed developments in mountain wilderness areas, would be of significant value to permitting agencies.

Avalanche Safety Basics

<u>Avalanches don't happen by accident</u> *and most human involvement is a matter of* ***<u>choice</u>*** *not chance. Slab avalanches, which are triggered by the victim or a member of the victim's party, cause most avalanche accidents. However, any avalanche may cause injury or death and even small slides may be dangerous. Hence, always practice safe route finding skills, be aware of changing conditions, and carry avalanche rescue gear. Learn and apply avalanche terrain analysis and snow stability evaluation techniques to help minimize your risk. Remember that avalanche danger rating levels are only general guidelines. Distinctions between geographic areas, elevations, slope aspect and slope angle are approximate, and transition zones between dangers exist. No matter what the current avalanche danger is, there are avalanche-safe areas in the mountains.*

UNITED STATES AVALANCHE DANGER DESCRIPTORS

Danger Level **(Color)**	Avalanche Probability and Avalanche Trigger	Degree and Distribution of Avalanche Danger	Recommended Action in the Back Country
Low **(Green)**	Natural Avalanches <u>very unlikely</u>. Human avalanches <u>unlikely</u>.	Generally stable snow. Isolated areas of instability.	Travel is generally safe. Normal caution advised.
Moderate **(yellow)**	Natural avalanches unlikely. Human triggered avalanches <u>possible</u>.	Unstable slabs <u>possible</u> on steep terrain.	Use caution on steeper terrain on certain aspects
Moderate to High **(orange)**	Natural avalanches <u>possible</u>. Human triggered avalanches <u>possible</u>.	Unstable slabs <u>possible</u> on steep terrain.	Be increasingly cautious in steep terrain.
High **(red)**	Natural and human triggered avalanches <u>likely</u>.	Unstable slabs <u>likely</u> on a variety of aspects and slope angles	Travel in avalanche terrain is not recommended. Safest travel on windward ridges of lower angle slopes without steeper terrain above.
Extreme **(red with black border)**	Widespread natural or human triggered avalanches are <u>certain</u>	Extremely unstable slabs are <u>certain</u> on most aspects and slope angles. Large destructive avalanches <u>possible</u>.	Travel in avalanche terrain should be avoided and travel confined to low angle terrain well away from avalanche path run-outs.

Figure 8-28. United States Avalanche Danger Scale

CHAPTER 9.

DAM FAILURE

9.1 GENERAL BACKGROUND

9.1.1 Causes of Dam Failure

Dam failures in the United States typically occur in one of four ways:

- Overtopping of the primary dam structure, which accounts for 34 percent of all dam failures, can occur due to inadequate spillway design, settlement of the dam crest, blockage of spillways, and other factors.
- Foundation defects due to differential settlement, slides, slope instability, uplift pressures, and foundation seepage can also cause dam failure. These account for 30 percent of all dam failures.
- Failure due to piping and seepage accounts for 20 percent of all failures. These are caused by internal erosion due to piping and seepage, erosion along hydraulic structures such as spillways, erosion due to animal burrows, and cracks in the dam structure.
- Failure due to problems with conduits and valves, typically caused by the piping of embankment material into conduits through joints or cracks, constitutes 10 percent of all failures.

The remaining 6 percent of U.S. dam failures are due to miscellaneous causes. Many dam failures in the United States have been secondary results of other disasters. The prominent causes are earthquakes, landslides, extreme storms, massive snowmelt, equipment malfunction, structural damage, foundation failures, and sabotage.

Poor construction, lack of maintenance and repair, and deficient operational procedures are preventable or correctable by a program of regular inspections. Terrorism and vandalism are serious concerns that all operators of public facilities must plan for; these threats are under continuous review by public safety agencies.

DEFINITIONS

- **Dam**—Any artificial barrier and/or any controlling works, together with appurtenant works, that can or does impound or divert water. (Washington Administrative Code, Title 173, Chapter 175.)

Dam Failure—An uncontrolled release of impounded water due to structural deficiencies in dam.

- **Emergency Action Plan**—A document that identifies potential emergency conditions at a dam and specifies actions to be followed to minimize property damage and loss of life. The plan specifies actions the dam owner should take to alleviate problems at a dam. It contains procedures and information to assist the dam owner in issuing early warning and notification messages to responsible downstream emergency management authorities of the emergency situation. It also contains inundation maps to show emergency management authorities the critical areas for action in case of an emergency. (FEMA 64)

High Hazard Dam—Dams where failure or operational error will probably cause loss of human life. (FEMA 333)

Significant Hazard Dam—Dams where failure or operational error will result in no probable loss of human life but can cause economic loss, environmental damage or disruption of lifeline facilities, or can impact other concerns. Significant hazard dams are often located in rural or agricultural areas but could be located in areas with population and significant infrastructure. (FEMA 333)

9.1.2 Regulatory Oversight

National Dam Safety Act

The potential for catastrophic flooding due to dam failures led to passage of the National Dam Safety Act (Public Law 92-367). The National Dam Safety Program requires a periodic engineering analysis of every major dam in the country. The goal of this FEMA-monitored effort is to identify and mitigate the risk of dam failure so as to protect the lives and property of the public.

Washington Department of Ecology Dam Safety Program

The Dam Safety Office (DSO) of the Washington Department of Ecology regulates over 1,000 dams in the state that impound at least 10 acre-feet of water. The DSO has developed dam safety guidelines to provide dam owners, operators, and design engineers with information on activities, procedures, and requirements involved in the planning, design, construction, operation and maintenance of dams in Washington. The authority to regulate dams in Washington and to provide for public safety is contained in the following laws:

- State Water Code (1917)—RCW 90.03
- Flood Control Act (1935)—RCW 86.16
- Department of Ecology (1970)—RCW 43.21A.

Where water projects involve dams and reservoirs with a storage volume of 10 acre-feet or more, the laws provide for the Department of Ecology to conduct engineering review of the construction plans and specifications, to inspect the dams, and to require remedial action, as necessary, to ensure proper operation, maintenance, and safe performance. The DSO was established within Ecology's Water Resources Program to carry out these responsibilities.

The DSO's five-year periodic inspection program for dams with high and significant hazard classifications achieves the following purposes (Washington Department of Ecology, 2011):

- Assess the structural integrity and stability of project elements.
- Identify obvious defects, especially due to aging.
- Assess the stability of the structure under earthquake conditions.
- Determine the adequacy of the spillways to accommodate major floods.
- Evaluate project operation and maintenance.

The inspections, performed by professional engineers from the DSO, consist of the following elements (Washington Department of Ecology, 2011):

- Review and analysis of available data on the design, construction, operation and maintenance of the dam and its appurtenances
- Visual inspection of the dam and its appurtenances
- Evaluation of the safety of the dam and its appurtenances, which may include an assessment of the hydrological and hydraulic capabilities, structural stabilities, seismic stabilities, and any other condition that could constitute a hazard to the integrity of the structure
- Evaluation of the downstream hazard classification
- Evaluation of the operation, maintenance and inspection procedures employed by the owner and/or operator

- Review of the emergency action plan for the dam, including review or update of the dam breach inundation map.

The DSO provides reasonable assurance that impoundment facilities will not pose a threat to lives and property, but dam owners bear primary responsibility for the safety of their structures, through proper design, construction, operation, and maintenance. The DSO regulates dams with the sole purpose of reasonably securing public safety; environmental and natural resource issues are addressed by other state agencies. The DSO neither advocates nor opposes the construction and operation of dams.

U.S. Army Corps of Engineers Dam Safety Program

The U.S. Army Corps of Engineers is responsible for safety inspections of some federal and non-federal dams in the United States that meet the size and storage limitations specified in the National Dam Safety Act. The Corps has inventoried dams; surveyed each state and federal agency's capabilities, practices and regulations regarding design, construction, operation and maintenance of the dams; and developed guidelines for inspection and evaluation of dam safety (U.S. Army Corps of Engineers, 1997).

Federal Energy Regulatory Commission Dam Safety Program

The Federal Energy Regulatory Commission (FERC) cooperates with a large number of federal and state agencies to ensure and promote dam safety. More than 3,000 dams are part of regulated hydroelectric projects in the FERC program. Two-thirds of these are more than 50 years old. As dams age, concern about their safety and integrity grows, so oversight and regular inspection are important. FERC inspects hydroelectric projects on an unscheduled basis to investigate the following:

- Potential dam safety problems
- Complaints about constructing and operating a project
- Safety concerns related to natural disasters
- Issues concerning compliance with the terms and conditions of a license.

Every five years, an independent engineer approved by the FERC must inspect and evaluate projects with dams higher than 32.8 feet (10 meters), or with a total storage capacity of more than 2,000 acre-feet.

FERC monitors and evaluates seismic research and applies it in investigating and performing structural analyses of hydroelectric projects. FERC also evaluates the effects of potential and actual large floods on the safety of dams. During and following floods, FERC visits dams and licensed projects, determines the extent of damage, if any, and directs any necessary studies or remedial measures the licensee must undertake. The FERC publication *Engineering Guidelines for the Evaluation of Hydropower Projects* guides the FERC engineering staff and licensees in evaluating dam safety. The publication is frequently revised to reflect current information and methodologies.

FERC requires licensees to prepare emergency action plans and conducts training sessions on how to develop and test these plans. The plans outline an early warning system if there is an actual or potential sudden release of water from a dam due to failure. The plans include operational procedures that may be used, such as reducing reservoir levels and reducing downstream flows, as well as procedures for notifying affected residents and agencies responsible for emergency management. These plans are frequently updated and tested to ensure that everyone knows what to do in emergency situations.

9.2 HAZARD PROFILE

9.2.1 Past Events

Three dam failure incidents have occurred in King County; accounting for all lives lost due to dam failure in the state (Washington Emergency Management Division, 2013).

- December 1918—Masonry Dam near North Bend had excessive seepage, which caused a mudflow, destroyed a railroad line and damaged the village of Eastwick; no lives lost.
- February 1932—Eastwick railroad fill failed. A slide caused railroad fill to back up and fail, destroyed a railroad line and damaged the village of Eastwick; 7 lives were lost.
- July 1976—Increased discharge from Mud Mountain Dam caused a surge in flow killing two children playing in the White River near Auburn.

Another major incident involving dam safety in King County occurred in 2009, when seepage issues were discovered at Howard Hanson Dam after a January flood event. The dam is on the Green River, and dam failure would result in extreme flooding of downstream communities in the Green River valley. The Army Corps of Engineers began improvements to reduce risk at the facility immediately after the seepage was discovered. Most of the construction improvements were completed by 2011 and the dam is now operating at its design capability (U.S. Army Corps of Engineers, 2012).

9.2.2 Location

In King County there are 122 dams that impound 10 acre-feet of water or more. Table 9 -17 lists the dams in King County that the Dam Safety Office rates as Hazard Class 1A, which is the highest-hazard classification for state regulated dams. Culmback Dam, located in Snohomish County also has the potential to impact residents and property in King County.

9.2.3 Frequency

Dam failure events are infrequent and usually coincide with events that cause them, such as earthquakes, landslides and excessive rainfall and snowmelt. There is a “residual risk” associated with dams. Residual risk is the risk that remains after safeguards have been implemented. For dams, the residual risk is associated with events beyond those that the facility was designed to withstand. However, the probability of any type of dam failure is low in today’s regulatory and dam safety oversight environment.

9.2.4 Severity

The Dam Safety Office classifies regulated dams in Washington by hazard class, based on the at-risk population living in the area that could be inundated if the dam fails. The hazard class definitions and number of King County dams in each class are as follows:

- 7 Hazard Class 1A (a downstream at-risk population of more than 300)
- 8 Hazard Class 1B (a downstream at-risk population of 31 to 300)
- 31 Hazard Class 1C (a downstream at-risk population of 7 to 30)
- 26 Hazard Class 2 (a downstream at-risk population of 1 to 6)
- 50 Hazard Class 3 (no downstream at-risk population).

**TABLE 9-17.
HAZARD CLASS 1A DAMS WITH POTENTIAL TO AFFECT KING COUNTY**

	Howard A Hanson Dam	Masonry Dam	Tolt River Dam	Lake Youngs Outlet Dam	Green Lake Reservoir	Issaquah Highlands Detention Pond	Madsen Creek West Basin Dam	Culmback Dam
National ID #	WA00298	WA00255	WA00177	WA00254	WA00212	WA00707	WA01862	WA00208
Water Course	Green River South	Cedar River	South Fork Tolt River	Little Soos Creek	Puget Sound Tributary, Off-stream	East Fork Issaquah Creek, Off-stream		Sultan River
Owner	U.S. Army Corps of Engineers	City of Seattle	Seattle Public Utilities	City of Seattle	Seattle Public Utilities	Port Blakely Communities	King County Natural Resources	Snohomish Co. Public Utility District
Year Built	1962	1914	1962	1921	1910	2008	2008	1965
Dam Type[a]	ER, RE	VA	RE	RE	RE	RE	RE	ER
Crest Length (feet)	500	980	980	1,450	1,920	380	775	900
Height (feet)	235	225	213	30	25	22	6.5	75
Storage Capacity (acre-feet)	136,700	175,000	67,200	18,908	181	53	28	16,200
Drainage area (sq. mi.)	221	81.4	18.8	3.94	0.02	0	0.11	2.6

a. RE = Earth fill; ER = Rock fill; VA = Concrete single arch

The U.S. Army Corps of Engineers developed the classification system shown in Table 9 -18 for the hazard potential of dam failures. The DSO and Corps of Engineers hazard rating systems are based only on the potential consequences of a dam failure; they do not take into account the probability of such failures.

According to the King County Office of Emergency Management, King County has four dams that would cause a countywide emergency if they should fail, located on the Tolt, Cedar, White, and Green Rivers. Areas of King County would also be adversely affected by failures of the White River Project in Pierce County or the Jackson Project in Snohomish County. Localized problems could occur if one of the minor dams in the county failed (King County Office of Emergency Management, 2013).

TABLE 9-18.
CORPS OF ENGINEERS HAZARD POTENTIAL CLASSIFICATION

Hazard Category[a]	Direct Loss of Life[b]	Lifeline Losses[c]	Property Losses[d]	Environmental Losses[e]
Low	None (rural location, no permanent structures for human habitation)	No disruption of services (cosmetic or rapidly repairable damage)	Private agricultural lands, equipment, and isolated buildings	Minimal incremental damage
Significant	Rural location, only transient or day-use facilities	Disruption of essential facilities and access	Major public and private facilities	Major mitigation required
High	Certain (one or more) extensive residential, commercial, or industrial development	Disruption of essential facilities and access	Extensive public and private facilities	Extensive mitigation cost or impossible to mitigate

a. Categories are assigned to overall projects, not individual structures at a project.
b. Loss of life potential based on inundation mapping of area downstream of the project. Analyses of loss of life potential should take into account the population at risk, time of flood wave travel, and warning time.
c. Indirect threats to life caused by the interruption of lifeline services due to project failure or operational disruption; for example, loss of critical medical facilities or access to them.
d. Damage to project facilities and downstream property and indirect impact due to loss of project services, such as impact due to loss of a dam and navigation pool, or impact due to loss of water or power supply.
e. Environmental impact downstream caused by the incremental flood wave produced by the project failure, beyond what would normally be expected for the magnitude flood event under which the failure occurs.

Source: U.S. Army Corps of Engineers, 1995

9.2.5 Warning Time

Warning time for dam failure varies depending on the cause of the failure. In events of extreme precipitation or massive snowmelt, evacuations can be planned with sufficient time. In the event of a structural failure due to earthquake, there may be no warning time. A dam’s structural type also affects warning time. Earthen dams do not tend to fail completely or instantaneously. Once a breach is initiated, discharging water erodes the breach until either the reservoir water is depleted or the breach resists further erosion. Concrete gravity dams also tend to have a partial breach as one or more monolith sections are forced apart by escaping water. The time of breach formation ranges from a few minutes to a few hours (U.S. Army Corps of Engineers, 1997).

King County and its planning partners have established protocols for flood warning and response to imminent dam failure in the flood warning portion of its adopted emergency operations plan. These protocols are tied to the emergency action plans created by the dam owners.

9.3 SECONDARY HAZARDS

Dam failure can cause severe downstream flooding, depending on the magnitude of the failure. Other potential secondary hazards of dam failure are landslides around the reservoir perimeter, bank erosion on the rivers, and destruction of downstream habitat.

9.4 EXPOSURE

The flood module of Hazus-MH was used for a Level 2 assessment of dam failure. Hazus-MH uses census data at the block level and FEMA floodplain data, which has a level of accuracy acceptable for planning purposes. Where possible, the Hazus-MH data for this risk assessment was enhanced using GIS data from county, state and federal sources. The exposure and vulnerability analyses focused on three dams for which inundation information was available: the Culmback Dam, the Tolt River Dam, and the Lake Youngs Dam. Inundation maps were prepared for this analysis, but will not be published in the publicly available version of this plan.

9.4.1 Population

All populations in a dam failure inundation zone would be exposed to the risk of a dam failure. The potential for loss of life is affected by the capacity and number of evacuation routes available to populations living in areas of potential inundation. The estimated population living in the mapped inundation areas within the planning area is 35,330 or 1.78 percent of the county's population. Table 9 -19 summarizes the at-risk population in the planning area by city, where there is available inundation mapping.

TABLE 9-19.
POPULATION WITHIN DAM FAILURE INUNDATION AREAS

	Affected Population by Individual Dam			Total Affected Population	% of City Population
	Tolt	Culmback	Lake Young's		
Auburn	0	0	9,058	9,058	14.08
Carnation	1,785	0	0	1,785	100
Covington	0	0	7,198	7,198	39.76
Duvall	235	159	0	394	5.53
Kent	0	0	2,121	2,121	1.76
Unincorporated	7,489	3,088	4,197	14,774	5.84
Total	0	0	0	**0**[a]	**1.78**[b]

a. Represents the total population in the combined inundation areas of all three evaluated dams.
b. Represents the total affected population as a percent of total King County population.

9.4.2 Property

The number and value of planning area buildings within the mapped inundation zones of the Tolt, Culmback and Lake Youngs dams are summarized in Table 9 -20 through Table 9 -22. Each dam should be considered to be a stand-alone hazard, considering the low probability of multiple dam failures at the same time. For that reason, and because the inundation areas for the Tolt and Culmback dams include some overlapping locations, it is not appropriate to add the totals for the three dams to generate a total planning area exposure estimate. The distribution of land uses in each dam's inundation area is in Table 9 -23 summarizes

**TABLE 9-20.
EXPOSURE AND VALUE OF STRUCTURES IN TOLT RIVER DAM FAILURE INUNDATION AREA**

	Buildings Exposed	Value Exposed			% of Total Assessed Value[a]
		Building	Contents	Total	
Carnation	822	$187,128,000	$138,939,000	$326,067,000	99.2
Duvall	99	$79,623,000	$70,141,000	$149,764,000	13.51
Unincorporated	3,160	$899,550,000	$554,805,000	$1,454,355,000	3.25
Total	0	0	0	0	**4.19**

a. Percentages are based on the total assessed value for individual jurisdictions, not for the planning area as a whole. The "total" percentage shown is based on the sum of assessed values for jurisdictions in this table.

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.3.5 for a discussion of data limitations.

**TABLE 9-21.
EXPOSURE AND VALUE OF STRUCTURES IN CULMBACK DAM FAILURE INUNDATION AREA**

	Buildings Exposed	Value Exposed			% of Total Assessed Value
		Building	Contents	Total	
Duvall	67	$68,147,000	$63,078,000	$131,225,000	11.84
Unincorporated	1,303	$423,784,000	$267,227,000	$691,011,000	1.55
Total	0	0	0	0	**1.80**

a. Percentages are based on the total assessed value for individual jurisdictions, not for the planning area as a whole. The "total" percentage shown is based on the sum of assessed values for jurisdictions in this table.

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.3.5 for a discussion of data limitations.

**TABLE 9-22.
EXPOSURE AND VALUE OF STRUCTURES IN LAKE YOUNGS DAM FAILURE INUNDATION AREA**

	Buildings Exposed	Value Exposed			% of Total Assessed Value
		Building	Contents	Total	
Auburn	3,822	$2,403,089,000	$2,026,574,000	$4,429,663,000	24.62
Covington	3,037	$1,026,586,000	$734,723,000	$1,761,309,000	61.81
Kent	895	$487,108,000	$427,277,000	$914,385,000	2.76
Unincorporated	1,771	$446,138,000	$253,335,000	$699,473,000	1.57
Total	0	0	0	0	**7.91**

a. Percentages are based on the total assessed value for individual jurisdictions, not for the planning area as a whole. The "total" percentage shown is based on the sum of assessed values for jurisdictions in this table.

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.3.5 for a discussion of data limitations.

**TABLE 9-23.
PRESENT LAND USE IN DAM INUNDATION AREAS**

Present Use Classification	Culmback Inundation Area Area (acres)	Culmback Inundation Area % of total	Lake Youngs Inundation Area Area (acres)	Lake Youngs Inundation Area % of total	Tolt Inundation Area Area (acres)	Tolt Inundation Area % of total
Agriculture	179	2.0%	63	0.9%	196	0.6%
Church, Welfare or Religious Service	12	0.1%	18	0.3%	21	0.1%
Commercial	85	1.0%	699	10.2%	511	1.7%
Education	0	0.0%	33	0.5%	62	0.2%
Governmental Services	0	0.0%	8	0.1%	3	0.0%
Industrial/Manufacturing	21	0.2%	228	3.3%	62	0.2%
Medical/Dental Services	1	0.0%	19	0.3%	1	0.0%
Mixed Use Development (Residential & Commercial)	0	0.0%	0	0.0%	0	0.0%
Mortuary/Cemetery/Crematory	0	0.0%	0	0.0%	2	0.0%
Nursing Home/Retirement Facility	0	0.0%	8	0.1%	0	0.0%
Park/Open Space/Golf Course	74	0.8%	382	5.6%	846	2.7%
Residential	3,760	42.9%	2,073	30.4%	8,183	26.5%
Terminal or Marina	0	0.0%	102	1.5%	12	0.0%
Utility/Easement/Right of Way	3	0.0%	205	3.0%	459	1.5%
Water/Tideland/Wetland	13	0.2%	83	1.2%	13	0.0%
Uncategorized (includes vacant and resource lands)	4,609	52.6%	2,905	42.6%	20,465	66.4%
Total	0	**100%**	0	**100%**	0	**100%**

Source: Summarized from King, Pierce and Snohomish County parcel data. Acreage covers only mapped parcels and thus excludes many rights of way and major water features.

9.4.3 Critical Facilities

GIS analysis determined the following numbers of critical facilities and infrastructure in each mapped inundation area (see Table 9 -24 through Table 9 -26):

- Culmback Dam—17 facilities (fewer than 1 percent)
- Lake Youngs Dam—27 facilities (fewer than 1 percent)
- Tolt Dam—59 facilities (1 percent).

Additional critical facilities are likely in inundation areas where mapping was not available.

9.4.4 Environment

The environment would be exposed to a number of risks in the event of dam failure. The inundation could introduce many foreign elements into local waterways. This could result in destruction of downstream

habitat and could have detrimental effects on many species of animals, especially endangered species such as salmon.

**TABLE 9-24.
CRITICAL FACILITIES AND INFRASTRUCTURE IN CULMBACK DAM INUNDATION AREA**

	Duvall	Unincorporated	**Total**
Medical and Health	0	0	**0**
Government Function	0	0	**0**
Protective Function	1	0	**1**
Schools	0	0	**0**
Hazmat	0	0	**0**
Other Critical Function	0	0	**0**
Bridges	1	14	**15**
Transportation	0	0	**0**
Water Supply	0	0	**0**
Wastewater	1	0	**1**
Power	0	0	**0**
Communications	0	0	**0**
Dams	0	0	**0**
Total	0	0	0

**TABLE 9-25.
CRITICAL FACILITIES AND INFRASTRUCTURE IN LAKE YOUNGS DAM INUNDATION AREA**

	Auburn	Covington	Kent	Unincorporated	**Total**
Medical and Health	0	3	0	0	**3**
Government Function	0	2	0	0	**2**
Protective Function	0	1	0	0	**1**
Schools	0	0	0	0	**0**
Hazmat	2	0	0	0	**2**
Other Critical Function	0	2	0	0	**2**
Bridges	0	6	2	1	**9**
Transportation	0	0	0	0	**0**
Water Supply	0	0	0	0	**0**
Wastewater	2	4	0	0	**6**
Power	0	1	0	0	**1**
Communications	1	0	0	0	**1**
Dams	0	0	0	0	**0**
Total	0	0	0	0	0

TABLE 9-26.
CRITICAL FACILITIES AND INFRASTRUCTURE IN TOLT DAM INUNDATION AREA

	Duvall	Carnation	Unincorporated	**Total**
Medical and Health	0	3	0	**3**
Government Function	0	0	0	**0**
Protective Function	1	2	0	**3**
Schools	0	4	0	**4**
Hazmat	0	0	0	**0**
Other Critical Function	0	0	0	**0**
Bridges	0	0	44	**44**
Transportation	0	0	0	**0**
Water Supply	0	0	0	**0**
Wastewater	1	0	0	**1**
Power	0	0	0	**0**
Communications	0	0	4	**4**
Dams	0	0	0	**0**
Total	0	0	0	0

9.5 VULNERABILITY

9.5.1 Population

Vulnerable populations are all populations downstream from dam failures that are incapable of escaping the area within the allowable time frame. This population includes the elderly and young who may be unable to get themselves out of the inundation area. The vulnerable population also includes those who would not have adequate warning from a television or radio emergency warning system. Impacts on persons and households in the planning area were estimated for dam failure events through the Level 2 Hazus-MH analysis. Table 9 -27 summarizes the results.

TABLE 9-27.
ESTIMATED DAM FAILURE IMPACT ON PERSONS AND HOUSEHOLDS

	Number of Displaced Households	Persons Requiring Short-Term Shelter
Tolt Dam Failure	3,195	2,404
Culmback Dam Failure	249	110
Lake Youngs Dam Failure	5,655	4,952

9.5.2 Property

Vulnerable properties are those closest to the dam inundation area. These properties would experience the largest, most destructive surge of water. Low-lying areas are also vulnerable since they are where the dam waters would collect. Transportation routes are vulnerable to dam inundation and have the potential to be

wiped out, creating isolation issues. This includes all roads, railroads and bridges in the path of the dam inundation. Those that are most vulnerable are those that are already in poor condition and would not be able to withstand a large water surge. Utilities such as overhead power lines, cable and phone lines could also be vulnerable. Loss of these utilities could create additional isolation issues for the inundation areas.

The estimated losses associated with planning area buildings within the mapped inundation zones of the Tolt, Culmback and Lake Youngs dams are summarized in Table 9 -28 through Table 9 -30. Each dam should be considered to be a stand-alone hazard, considering the low probability of multiple dam failures at the same time. For that reason, and because the inundation areas for the Tolt and Culmback dams include some overlapping locations, it is not appropriate to add the totals for the three dams to generate a total planning area loss estimate.

TABLE 9-28.
LOSS ESTIMATES FOR STRUCTURES IN TOLT RIVER DAM FAILURE INUNDATION AREA

	Estimated Loss Associated with Dam Failure			% of Total Assessed Value[a]
	Building	Contents	Total	
Carnation	$122,464,000	$111,251,000	$233,715,000	71.17
Duvall	$4,704,000	$7,594,000	$12,298,000	1.11
Unincorporated	$94,792,000	$82,819,000	$177,611,000	0.40
Total	0	0	0	**0.92**

a. Percentages are based on the total assessed value for individual jurisdictions, not for the planning area as a whole. The "total" percentage shown is based on the sum of assessed values for jurisdictions in this table.

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.3.5 for a discussion of data limitations.

TABLE 9-29.
LOSS ESTIMATES FOR STRUCTURES IN CULMBACK DAM FAILURE INUNDATION AREA

	Estimated Loss Associated with Dam Failure			% of Total Assessed Value[a]
	Building	Contents	Total	
Duvall	$2,200,000	$3,772,000	$5,972,000	0.54
Unincorporated	$9,934,000	$8,802,000	$18,736,000	0.04
Total	0	0	0	**0.05**

a. Percentages are based on the total assessed value for individual jurisdictions, not for the planning area as a whole. The "total" percentage shown is based on the sum of assessed values for jurisdictions in this table.

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.3.5 for a discussion of data limitations.

**TABLE 9-30.
LOSS ESTIMATES FOR STRUCTURES IN LAKE YOUNGS DAM FAILURE INUNDATION AREA**

	Estimated Loss Associated with Dam Failure			% of Total Assessed Value[a]
	Building	Contents	Total	
Auburn	$144,115,000	$327,238,000	$471,353,000	2.62
Covington	$62,272,000	$86,249,000	$148,521,000	5.21
Kent	$17,925,000	$33,668,000	$51,593,000	0.16
Unincorporated	$17,714,000	$16,043,000	$33,757,000	0.08
Total	0	0	0	**0.74**

a. Percentages are based on the total assessed value for individual jurisdictions, not for the planning area as a whole. The "total" percentage shown is based on the sum of assessed values for jurisdictions in this table.

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.3.5 for a discussion of data limitations.

9.5.3 Critical Facilities

On average, critical facilities expected to sustain damage during a dam failure event would receive 23 percent damage to the structure and 75 percent damage to the contents during a dam failure event. The estimated time to restore these facilities to 100 percent of their functionality is 716 days.

9.5.4 Environment

The environment would be vulnerable to a number of risks in the event of dam failure. The inundation could introduce foreign elements into local waterways, resulting in destruction of downstream habitat and detrimental effects on many species of animals, especially endangered species such as coho salmon. The extent of the vulnerability of the environment is the same as the exposure of the environment.

As with any significant natural hazard event, large of amounts of debris generated from the damages buildings and infrastructure could have significant environmental impacts. These impacts were estimated for the dam failure events through the Level 2 Hazus-MH analysis. Table 9 -31 summarizes the results.

**TABLE 9-31.
ESTIMATED DAM FAILURE-CAUSED DEBRIS**

	Debris to Be Removed (tons)[a]
Tolt Dam Failure Scenario	24.19 million
Culmback Dam Failure Scenario	2.77 million
Lake Young's Dam Failure Scenario	64.2 million

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.3.5 for a discussion of data limitations.

9.6 FUTURE TRENDS IN DEVELOPMENT

Land use in the planning area will be directed by local comprehensive plans, adopted under state law. The planning partners have established comprehensive policies regarding sound land use in identified flood hazard areas. While some of the areas vulnerable to the more severe impacts from dam failure intersect the mapped flood hazard areas, the inundation areas from a dam failure cover a much larger portion of the planning area. Flood-related policies in these comprehensive plans and in the local municipal code will help to reduce the risk associated with the dam failure hazard for development in the planning area, but will be unlikely to help reduce risk to all structures within the dam inundation area.

9.7 SCENARIO

An earthquake in the region could lead to liquefaction of soils around a dam. This could occur without warning during any time of the day. A human-caused incident such as a terrorist attack also could trigger a catastrophic failure of a dam that impacts the planning area. Failure of a high hazard dam in the county would likely result in the loss of life, roadways, structures and property and cause severe impacts on the local economy. While the possibility of failure is remote, results of such an event would be devastating.

While the probability of dam failure is very low, the probability of flooding associated with changes to dam operational parameters in response to climate change is higher. Dam designs and operations are developed based on hydrographs from historical records. If these hydrographs experience significant changes over time due to the impacts of climate change, the dam design and operations may no longer be valid for the changed condition. Specified release rates and impound thresholds may have to be changed. This would result in increased discharges downstream of these facilities, thus increasing the probability and severity of flooding.

9.8 ISSUES

In the late 1980s, the Department of Ecology DSO was reorganized to better use its resources to minimize public safety problems. The DSO has recognized the key role of other government agencies in carrying out its public safety charge. For example, the dam approval process now requires that dams located above populated areas develop emergency action plans in conjunction with local and county emergency management agencies.

The most significant issue associated with dam failure involves properties and populations in the inundation zones. Flooding as a result of a dam failure would significantly impact these areas. In certain scenarios there would be little or no warning time for dam failure. Dam failure events are frequently associated with other natural hazard events such as earthquakes, landslides or severe weather, which limits their predictability and compounds the hazard. Important issues associated with dam failure hazards include the following:

- It is unclear whether dam failure warning and notification strategies will be viable if dam failure occurs as a result of a significant earthquake that interrupts communication systems.
- Changes in hydrographs in the region as a result of climate change are likely to include more instances of winter flooding. This could alter dam operations and increase the potential for design failures.
- Downstream populations are often not aware that they are located in a dam failure inundation area and do not know the risks associated with probable dam failure.
- Balancing the need to address security concerns and the need to inform the public of the risk associated with dam failure is a challenge for public officials.

- Dam failure inundation areas are often not considered special flood hazard areas under the National Flood Insurance Program, so flood insurance coverage in these areas is not common.
- Most dam failure mapping required at federal levels requires determination of the probable maximum flood. While the probable maximum flood represents a worst-case scenario, it is generally the event with the lowest probability of occurrence. For non-federal-regulated dams, mapping of dam failure scenarios that are less extreme than the probable maximum flood but have a higher probability of occurrence can be valuable to emergency managers and community officials downstream of these facilities. This type of mapping can show areas potentially impacted by more frequent events, to be used in support of emergency response and preparedness measures.

CHAPTER 10.

EARTHQUAKE

10.1 GENERAL BACKGROUND

10.1.1 How Earthquakes Happen

An earthquake is the vibration of the earth's surface following a release of energy in the earth's crust. This energy can be generated by a sudden dislocation of the crust or by a volcanic eruption. Most destructive quakes are caused by dislocations of the crust. The crust may first bend and then, when the stress exceeds the strength of the rocks, break and snap to a new position. In the process of breaking, vibrations called "seismic waves" are generated. These waves travel outward from the source of the earthquake at varying speeds.

Earthquakes tend to reoccur along faults, which are zones of weakness in the crust. Even if a fault zone has recently experienced an earthquake, there is no guarantee that all the stress has been relieved. Another earthquake could still occur.

DEFINITIONS

Earthquake—The shaking of the ground caused by an abrupt shift of rock along a fracture in the earth or a contact zone between tectonic plates.

- **Epicenter**—The point on the earth's surface directly above the hypocenter of an earthquake. The location of an earthquake is commonly described by the geographic position of its epicenter and by its focal depth.

Fault—A fracture in the earth's crust along which two blocks of the crust have slipped with respect to each other.

Focal Depth—The depth from the earth's surface to the hypocenter.

Hypocenter—The region underground where an earthquake's energy originates

Liquefaction—Loosely packed, water-logged sediments losing their strength in response to strong shaking, causing major damage during earthquakes.

10.1.2 Types of Earthquakes

The earth's crust is divided into eight major pieces (or plates) and many minor plates. In Western Washington, the primary plates of interest are the Juan De Fuca and North American plates. The Juan De Fuca plate moves northeastward with respect to the North America plate at a rate of about 3 to 4 centimeters per year. The boundary where these two plates converge, the Cascadia Subduction Zone, lies approximately 50 miles offshore and extends from the middle of Vancouver Island in British Columbia to northern California. As it collides with North America, the Juan De Fuca plate slides beneath the continent and sinks into the earth's mantle. More than 90 percent of Pacific Northwest earthquakes occur along the boundary between the Juan de Fuca plate and the North American plate. The collision of the Juan De Fuca and North America plates produces three types of earthquakes, as shown on Figure 10 -29 and described below.

Subduction Zone Earthquakes

Subduction Zone earthquakes occur at the interface between tectonic plates. A subduction zone earthquake affecting King County would be centered in the Cascadia Subduction zone off the coast of Washington or Oregon. Such earthquakes typically have a minute or more of strong ground shaking, and are quickly followed by damaging tsunamis and numerous large aftershocks. The potential exists for large earthquakes along the Cascadia Subduction Zone, up to an earthquake measuring 9 or more on the Richter

scale. This would cause coastal areas to drop up to 6 feet in minutes and would produce a tsunami all along the fault line from British Columbia to Mendocino, California. Such an earthquake would last several minutes and produce catastrophic damage.

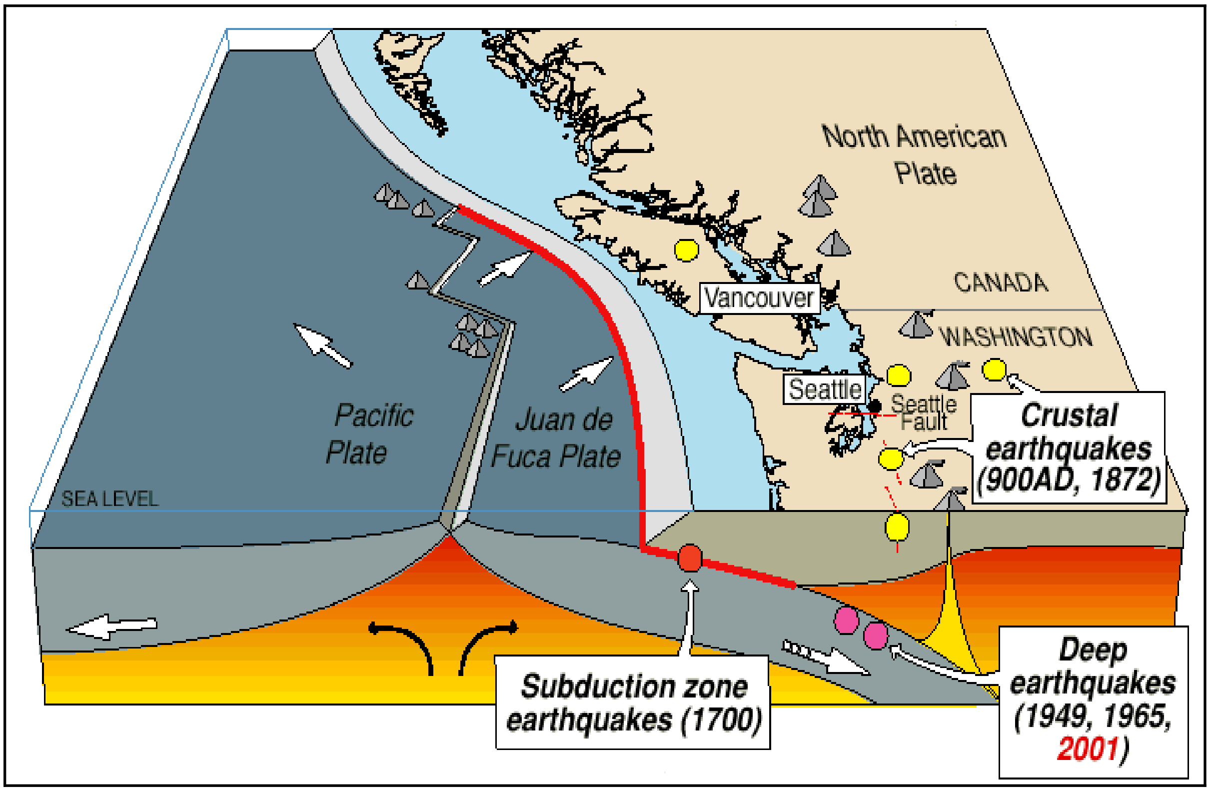


Figure 10-29. Earthquake Types in the Pacific Northwest

Benioff Zone (Deep) Earthquakes

Benioff Zone earthquakes occur within the Juan De Fuca plate as it sinks into the mantle. These are primarily deep earthquakes, 25 to 100 kilometers in depth. Due to their depth, aftershocks are typically not felt in association with these earthquakes. These earthquakes are caused by mineral changes as the plate moves deeper into the mantle. Minerals that make up the plates are altered to denser, more stable forms as temperature and pressure increase. This results in a decrease in the size of the plate, and stresses build up that pull the plate apart (Washington Department of Natural Resources, 2014). Deep earthquakes generally last 20 to 30 seconds and have the potential of reaching 7.5 on the Richter scale. The last major one in the Puget Sound region was the 6.8 magnitude Nisqually Earthquake on February 28, 2001.

Shallow Crustal Earthquakes

Shallow crustal earthquakes occur within the North America plate at depths of 30 kilometers or less. Shallow earthquakes within the North America plate account for most of the earthquakes in the Puget Sound region. Most are relatively small but the potential exists for major shallow earthquakes as well. Generally, these earthquakes are expected to have magnitudes less than 8 and last from 20 to 60 seconds.

Of the three types of earthquake, crustal events are the least understood. Ongoing research suggests that Magnitude 7 or greater events have occurred on at least eight faults in the Puget Sound basin. Large

events on these faults have the potential to cause greater loss of life and property than any other disaster likely to affect the area. It is estimated that the St. Helens seismic zone could produce a Magnitude 6.2 to 6.8 earthquake. Evidence of a fault running east-west through south Seattle (the Seattle Fault) suggests that a major earthquake with a magnitude of 7 or greater affected the Seattle area about 1,100 years ago.

10.1.3 Faults

Earthquakes tend to reoccur along faults, which are zones of weakness in the crust. Even if a fault zone has recently experienced an earthquake, there is no guarantee that all the stress has been relieved. Another earthquake could still occur.

Geologists classify faults by their relative hazards. Active faults, which represent the highest hazard, are those that have ruptured to the ground surface during the Holocene period (about the last 11,000 years). Potentially active faults are those that displaced layers of rock from the Quaternary period (the last 1,800,000 years). Determining if a fault is “active” or “potentially active” depends on geologic evidence, which may not be available for every fault. Although there are probably still some unrecognized active faults, nearly all the movement between the two plates, and therefore the majority of the seismic hazards, are on the well-known active faults.

Faults are more likely to have earthquakes on them if they have more rapid rates of movement, have had recent earthquakes along them, experience greater total displacements, and are aligned so that movement can relieve accumulating tectonic stresses. A direct relationship exists between a fault’s length and location and its ability to generate damaging ground motion at a given site. In some areas, smaller, local faults produce lower magnitude quakes, but ground shaking can be strong, and damage can be significant as a result of the fault’s proximity to the area. In contrast, large regional faults can generate great magnitudes but, because of their distance and depth, may result in only moderate shaking in the area.

10.1.4 Earthquake Classifications

Earthquakes are typically classified in one of two ways: By the amount of energy released, measured as **magnitude**; or by the impact on people and structures, measured as **intensity**.

Magnitude

Currently the most commonly used magnitude scale is the moment magnitude (M_w) scale, with the follow classifications of magnitude:

- Great—$M_w \geq 8$
- Major—$M_w = 7.0 - 7.9$
- Strong—$M_w = 6.0 - 6.9$
- Moderate—$M_w = 5.0 - 5.9$
- Light—$M_w = 4.0 - 4.9$
- Minor—$M_w = 3.0 - 3.9$
- Micro—$M_w < 3$

Estimates of moment magnitude roughly match the local magnitude scale (ML) commonly called the Richter scale. One advantage of the moment magnitude scale is that, unlike other magnitude scales, it does not saturate at the upper end. That is, there is no value beyond which all large earthquakes have about the same magnitude. For this reason, moment magnitude is now the most often used estimate of large earthquake magnitudes.

Intensity

Currently the most commonly used intensity scale is the modified Mercalli intensity scale, with ratings defined as follows (USGS, 1989):

- I. Not felt except by a very few under especially favorable conditions
- II. Felt only by a few persons at rest, especially on upper floors of buildings.
- III. Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it is an earthquake. Standing cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
- IV. Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like a heavy truck striking building. Standing cars rocked noticeably.
- V. Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
- VI. Felt by all; many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
- VII. Damage negligible in buildings of good design and construction; slight in well-built ordinary structures; considerable in poorly built or badly designed structures. Some chimneys broken.
- VIII. Damage slight in specially designed structures; considerable damage in ordinary buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
- IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
- X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.
- XI. Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.
- XII. Damage total. Lines of sight and level are distorted. Objects thrown into the air.

10.1.5 Ground Motion

Earthquake hazard assessment is also based on expected ground motion. This involves determining the annual probability that certain ground motion accelerations will be exceeded, then summing the annual probabilities over the time period of interest. The most commonly mapped ground motion parameters are the horizontal and vertical peak ground accelerations (PGA) for a given soil or rock type. Instruments called accelerographs record levels of ground motion due to earthquakes at stations throughout a region. These readings are recorded by state and federal agencies that monitor and predict seismic activity.

Maps of PGA values form the basis of seismic zone maps that are included in building codes such as the International Building Code. Building codes that include seismic provisions specify the horizontal force due to lateral acceleration that a building should be able to withstand during an earthquake. PGA values are directly related to these lateral forces that could damage “short period structures” (e.g. single-family dwellings). Longer period response components determine the lateral forces that damage larger structures with longer natural periods (apartment buildings, factories, high-rises, bridges). Table 10 -32 lists damage potential and perceived shaking by PGA factors, compared to the Mercalli scale.

TABLE 10-32.
MERCALLI SCALE AND PEAK GROUND ACCELERATION COMPARISON

Modified Mercalli Scale	Perceived Shaking	Potential Structure Damage: Resistant Buildings	Potential Structure Damage: Vulnerable Buildings	Estimated PGA[a] (%g)
I	Not Felt	None	None	<0.17%
II-III	Weak	None	None	0.17% - 1.4%
IV	Light	None	None	1.4% - 3.9%
V	Moderate	Very Light	Light	3.9% - 9.2%
VI	Strong	Light	Moderate	9.2% - 18%
VII	Very Strong	Moderate	Moderate/Heavy	18% - 34%
VIII	Severe	Moderate/Heavy	Heavy	34% - 65%
IX	Violent	Heavy	Very Heavy	65% - 124%
X - XII	Extreme	Very Heavy	Very Heavy	>124%

a. PGA measured in percent of g, where g is the acceleration of gravity
Sources: USGS, 2008; USGS, 2010

10.1.6 Effect of Soil Types

The impact of an earthquake on structures and infrastructure is largely a function of ground shaking, distance from the source of the quake, and liquefaction, a secondary effect of an earthquake in which soils lose their shear strength and flow or behave as liquid, thereby damaging structures that derive their support from the soil. Liquefaction generally occurs in soft sedimentary soils. A program called the National Earthquake Hazard Reduction Program (NEHRP) creates maps based on soil characteristics to help identify locations subject to liquefaction. Table 10 -33 summarizes NEHRP soil classifications. NEHRP Soils B and C typically can sustain ground shaking without much effect, dependent on the earthquake magnitude. The areas that are commonly most affected by ground shaking have NEHRP Soils D, E and F. In general, these areas are also most susceptible to liquefaction.

TABLE 10-33.
NEHRP SOIL CLASSIFICATION SYSTEM

NEHRP Soil Type	Description	Mean Shear Velocity to 30 m (m/s)
A	Hard Rock	1,500
B	Firm to Hard Rock	760-1,500
C	Dense Soil/Soft Rock	360-760
D	Stiff Soil	180-360
E	Soft Clays	< 180
F	Special Study Soils (liquefiable soils, sensitive clays, organic soils, soft clays >36 m thick)	

10.2 HAZARD PROFILE

Earthquakes can last from a few seconds to over five minutes; they may also occur as a series of tremors over several days. The actual movement of the ground in an earthquake is seldom the direct cause of injury or death. Casualties generally result from falling objects and debris, because the shocks shake, damage or demolish buildings and other structures. Disruption of communications, electrical power supplies and gas, sewer and water lines should be expected. Earthquakes may trigger fires, dam failures, landslides or releases of hazardous material, compounding their disastrous effects. Small, local faults produce lower magnitude quakes, but ground shaking can be strong and damage can be significant in areas close to the fault. In contrast, large regional faults can generate earthquakes of great magnitudes but, because of their distance and depth, they may result in only moderate shaking in an area.

10.2.1 Past Events

There are about a dozen fault zones in the Puget Sound lowlands. Evidence exists that Magnitude 7 or greater earthquakes have occurred on at least eight of these—the Seattle Fault, the Tacoma Fault, the Darrington-Devils Mountain Fault, the Utsalady Point Fault, the Southern Whidbey Island Fault, the Frigid Creek Fault, the Canyon River Fault, and the Lake Creek Fault. Each year more than a thousand earthquakes are recorded in Washington. Fifteen to 20 of these are strong enough to be felt. Seismic events that have been felt in or have impacted King County since 1945 are listed in Table 10 -34. Earthquakes that caused damage occurred in the county in 1909, 1939, 1946, 1949, 1965 and 2001.

TABLE 10-34.
HISTORICAL EARTHQUAKES IMPACTING THE PLANNING AREA

Year	Magnitude	Region Impacted	Year	Magnitude	Region Impacted
1945	5.7	SSE of North Bend	1997	3.1	Duvall
1949	7.1	ENE of Olympia	1998	2.9	Seattle
1965	6.5	N of Tacoma	1998	3.1	Pierce County
1995	5.0	NNE Tacoma	1998	2.9	Skykomish
1996	5.4	ENE of Duvall	1999	3.9	Tacoma
1996	2.9	Puget Sound	2001	7.2	Nisqually - Olympia
1997	3.0	SE of Seattle	2002	4.2	Friday Harbor, San Juan Islands
1997	4.9	Puget Sound off Vashon Island	2003	3.7	Bremerton, Kitsap County
1997	2.7	Puget Sound	2009	4.5	Bremerton

10.2.2 Location

Identifying the extent and location of an earthquake is not as simple as it is for other hazards such as flood, landslide or wild fire. The impact of an earthquake is largely a function of the following components:

- Ground shaking (ground motion accelerations)
- Liquefaction (soil instability)
- Distance from the source (both horizontally and vertically).

Mapping that shows the impacts of these components was used to assess the risk of earthquakes within the planning area. While the impacts from each of these components can build upon each other during an earthquake event, the mapping looks at each component individually. The mapping used in this assessment is described below.

In 1993, the U.S. Geological Survey began developing a database for Quaternary faults and folds for the United States. The database includes information on geographic, geologic, and seismic parameters for making assessments of seismic hazards. Figure 10 -30 shows the identified faults within the planning area.

Shake Maps

A shake map is a representation of ground shaking produced by an earthquake. The information it presents is different from the earthquake magnitude and epicenter that are released after an earthquake because shake maps focus on the ground shaking resulting from the earthquake, rather than the parameters describing the earthquake source. An earthquake has only one magnitude and one epicenter, but it produces a range of ground shaking at sites throughout the region, depending on the distance from the earthquake, the rock and soil conditions at sites, and variations in the propagation of seismic waves from the earthquake due to complexities in the structure of the earth's crust. A shake map shows the extent and variation of ground shaking in a region immediately following significant earthquakes.

Ground motion and intensity maps are derived from peak ground motion amplitudes recorded on seismic sensors (accelerometers), with interpolation based on estimated amplitudes where data are lacking, and site amplification corrections. Color-coded instrumental intensity maps are derived from empirical relations between peak ground motions and Modified Mercalli intensity. Two types of shake map are typically generated from the data:

- A probabilistic seismic hazard map shows the hazard from earthquakes that geologists and seismologists agree could occur. The maps are expressed in terms of probability of exceeding a certain ground motion, such as the 10-percent probability of exceedance in 50 years. This level of ground shaking has been used for designing buildings in high seismic areas. Figure 10 -31 and Figure 10 -32 show the estimated ground motion for the 100-year and 500-year probabilistic earthquakes in the planning area.
- Earthquake scenario maps describe the expected ground motions and effects of hypothetical large earthquakes for a region. Maps of these scenarios can be used to support all phases of emergency management. Three scenarios were chosen for this plan:
  - Seattle Fault Scenario—A Magnitude 7.2 event with a shallow depth and epicenter approximately 6 miles south-southwest of downtown Seattle. See Figure 10 -33
  - South Whidbey Island Fault Scenario—A Magnitude 7.4 event with a shallow depth and epicenter approximately 13.5 miles west-northwest of Everett. See Figure 10 -34.
  - Tacoma Fault Scenario—A Magnitude 7.1 event with a shallow depth and epicenter approximately 16.5 miles northwest of Tacoma. See Figure 10 -35.

NEHRP Soil Maps

NEHRP soil types define the locations that will be significantly impacted by an earthquake. NEHRP Soils B and C typically can sustain low-magnitude ground shaking without much effect. The areas that are most commonly affected by ground shaking have NEHRP Soils D, E and F. Figure 10 -36 shows NEHRP soil classifications in King County.

Insert Faults Map

Figure 10-30. Planning Area Active Faults and Folds

Insert 100-Year Earthquake Map

Figure 10-31. Planning Area 100-Year Probability Earthquake Event Peak Ground Acceleration

Insert 500-Year Earthquake Map

Figure 10-32. Planning Area 500-Year Probability Earthquake Event Peak Ground Acceleration

Insert Seattle Fault Scenario Earthquake Map

Figure 10-33. Seattle Fault - M7.2 Scenario Peak Ground Acceleration

Insert South Whidbey Fault Scenario Earthquake Map

Figure 10-34. South Whidbey Island Fault - M7.4 Scenario Peak Ground Acceleration

Insert Tacoma Fault Scenario Earthquake Map

Figure 10-35. Tacoma Fault - M7.1 Scenario Peak Ground Acceleration

Insert NEHRP Soils Map

Figure 10-36. National Earthquake Hazard Reduction ProgramSoil Classification

Liquefaction Maps

Soil liquefaction maps are useful tools to assess potential damage from earthquakes. When the ground liquefies, sandy or silty materials saturated with water behave like a liquid, causing pipes to leak, roads and airport runways to buckle, and building foundations to be damaged. In general, areas with NEHRP Soils D, E and F are also susceptible to liquefaction. If there is a dry soil crust, excess water will sometimes come to the surface through cracks in the confining layer, bringing liquefied sand with it, creating sand boils. Figure 10 -37 shows the liquefaction susceptibility in the planning area.

10.2.3 Frequency

The recurrence rate for a Magnitude 6.5 or greater earthquake is estimated to be about 350 years anywhere in the Puget Sound basin and 1,000 years on the Seattle Fault (Washington Emergency Management Division, 2014). In general, it is difficult to estimate the probability of occurrence of crustal earthquake events. Earthquakes on the South Whidbey Island and Seattle Faults have a 2 percent probability of occurrence in 50 years. The USGS estimated that a crustal zone earthquake has a recurrence interval of about 500 to 600 years.

Recurrence intervals for Benioff Zone earthquakes are estimated to be 30 to 40 years for Magnitude 6.5 and 50 to 100 years for Magnitude 7.0. A Benioff Zone earthquake has an 85 percent probability of occurrence in 50 years, making it the most likely of the three types.

Earthquake events occurring along the Cascadia Subduction Zone reoccur with far less frequency. Such events occur on average every 550 years, although the recurrence interval appears to be irregular. The intervals between earthquakes in this subduction zone have ranged from 100 years to more than 1,000 years. The USGS estimated that a Cascadia Subduction Zone earthquake has a 10 to 15 percent probability of occurrence in 50 years.

10.2.4 Severity

The severity of an earthquake can be expressed in terms of intensity or magnitude. Intensity represents the observed effects of ground shaking on people, buildings, and natural features. The USGS has created ground motion maps based on current information about several fault zones. These maps show the PGA that has a certain probability (2 percent or 10 percent) of being exceeded in a 50-year period. The PGA is measured in numbers of g’s (the acceleration associated with gravity). Figure 10 -38 shows the PGAs with a 2-percent exceedance chance in 50 years in Washington. King County is a medium- to high-risk area.

Magnitude is related to the amount of seismic energy released at the hypocenter of an earthquake. It is determined by the amplitude of the earthquake waves recorded on instruments. Whereas intensity varies depending on location with respect to the earthquake epicenter, magnitude is represented by a single, instrumentally determined value for each earthquake event. In simplistic terms, the severity of an earthquake event can be measured in the following terms:

- How hard did the ground shake?
- How did the ground move? (Horizontally or vertically)
- How stable was the soil?
- What is the fragility of the built environment in the area of impact?

Insert Liquefaction Map

Figure 10-37. Liquefaction Susceptibility

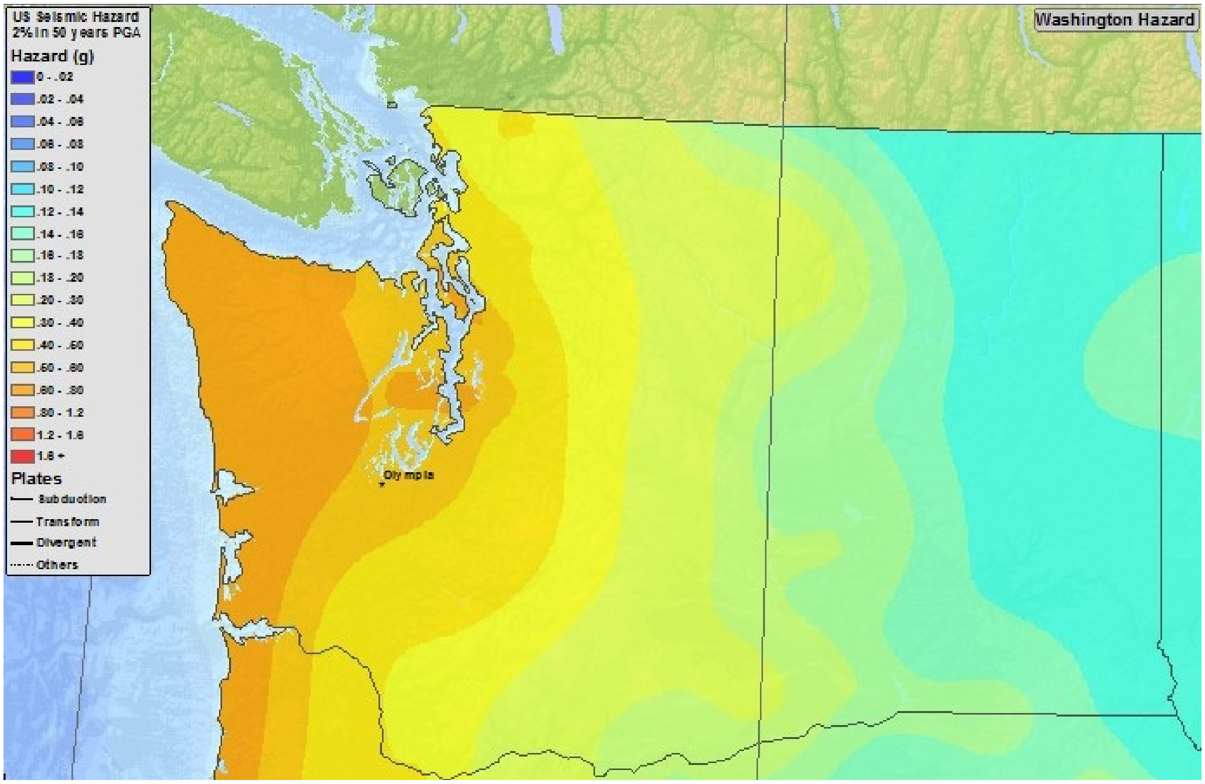


Figure 10-38. PGA with 2-Percent Probability of Exceedance in 50 Years, Northwest Region

10.2.5 Warning Time

There is currently no reliable way to predict the day or month that an earthquake will occur at any given location. Research is being done with warning systems that use the low energy waves that precede major earthquakes. These potential warning systems give approximately 40 seconds notice that a major earthquake is about to occur. The warning time is very short but it could allow for someone to get under a desk, step away from a hazardous material they are working with, or shut down a computer system.

10.3 SECONDARY HAZARDS

Earthquakes can cause large and sometimes disastrous landslides and mudslides. River valleys are vulnerable to slope failure, often as a result of loss of cohesion in clay-rich soils. Soil liquefaction occurs when water-saturated sands, silts or gravelly soils are shaken so violently that the individual grains lose contact with one another and float freely in the water, turning the ground into a pudding-like liquid. Building and road foundations lose load-bearing strength and may sink into what was previously solid ground. Unless properly secured, hazardous materials can be released, causing significant damage to the environment and people. Earthen dams and levees are highly susceptible to seismic events and the impacts of their eventual failures can be considered secondary risks for earthquakes. Disruptions in utility services including power, communication, gas, wastewater and potable water may also occur.

10.4 EXPOSURE

10.4.1 Population

The entire population of King County is potentially exposed to direct and indirect impacts from earthquakes. The degree of exposure is dependent on many factors, including the age and construction

type of the structures people live in, the soil type their homes are constructed on, their proximity to fault location, etc. Whether directly impacted or indirectly impact, the entire population will have to deal with the consequences of earthquakes to some degree. Business interruption could keep people from working, road closures could isolate populations, and loss of functions of utilities could impact populations that suffered no direct damage from an event itself.

10.4.2 Property

According to County Assessor records, there are 545,846 buildings in the planning area, with a total assessed value of $556.7 billion. Since all structures in the planning area are susceptible to earthquake impacts to varying degrees, this total represents the countywide property exposure to seismic events. Most of the buildings (87.6 percent) are residential.

10.4.3 Critical Facilities and Infrastructure

All critical facilities in the planning area are exposed to the earthquake hazard. Table 6 -13 and Table 6 -14 list the number of each type of facility by jurisdiction. Hazardous materials releases can occur during an earthquake from fixed facilities or transportation-related incidents. Transportation corridors can be disrupted during an earthquake, leading to the release of materials to the surrounding environment. Facilities holding hazardous materials are of particular concern because of possible isolation of neighborhoods surrounding them. During an earthquake, structures storing these materials could rupture and leak into the surrounding area or an adjacent waterway, having a disastrous effect on the environment.

10.4.4 Environment

Secondary hazards associated with earthquakes will likely have some of the most damaging effects on the environment. Earthquake-induced landslides can significantly impact surrounding habitat. It is also possible for streams to be rerouted after an earthquake. This can change the water quality, possibly damaging habitat and feeding areas. There is a possibility of streams fed by groundwater drying up because of changes in underlying geology.

10.5 VULNERABILITY

Earthquake vulnerability data was generated using a Level 2 Hazus-MH analysis. Once the location and size of a hypothetical earthquake are identified, Hazus-MH estimates the intensity of the ground shaking, the number of buildings damaged, the number of casualties, the damage to transportation systems and utilities, the number of people displaced from their homes, and the estimated cost of repair and clean up.

10.5.1 Population

There are estimated to be 611,662 people in over 250,000 households living on NEHRP Class D or E soils within the planning area. This represents about 30 percent of the total population. Of this population, two groups are particularly vulnerable to earthquake hazards.

- **Population Below Poverty Level**—An estimated 37,857 households in the planning area census blocks on NEHRP D and E soils have household incomes less than $20,000 per year. This is about 15 percent of all households located on Class D and E soils. These households may lack the financial resources to improve their homes to prevent or mitigate earthquake damage. Poorer residents are also less likely to have insurance to compensate for losses in earthquakes.
- **Population Over 65 Years Old**—An estimated 63,530 residents in the planning area census blocks on NEHRP D and E soils are over 65 years old. This is about 10 percent of all residents in

these census blocks. This population group is vulnerable because they are more likely to need special medical attention, which may not be available due to isolation caused by earthquakes. Elderly residents also have more difficulty leaving their homes during earthquake events and could be stranded in dangerous situations.

Impacts on persons and households in the planning area were estimated for the 100-year and 500-year earthquakes and the three scenario events through the Level 2 Hazus-MH analysis. Table 10 -35 summarizes the results.

TABLE 10-35.
ESTIMATED EARTHQUAKE IMPACT ON PERSONS AND HOUSEHOLDS

	Number of Displaced Households	Number of Persons Requiring Short-Term Shelter
100-Year Earthquake	6,016	3,192
500-Year Earthquake	29,204	15,613
Seattle Fault, M7.2 Scenario	27,205	14,657
South Whidbey Island Fault, M7.4 Scenario	3,579	1,855
Tacoma Fault, M 7.1 Scenario	8,737	5,551

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.3.5 for a discussion of data limitations.

10.5.2 Property

Building Age

Table 10 -36 identifies significant milestones in building and seismic code requirements that directly affect the structural integrity of development. Using these time periods, the planning team used King County Assessor's data to identify the number of structures in the planning area by date of construction.

The number of structures does not reflect the number of total housing units, as many multi-family units and attached housing units are reported as one structure. Approximately 21.7 percent of the planning area's structures were constructed after the Uniform Building Code was amended in 1994 to include seismic safety provisions. Approximately 11.9 percent were built before 1933 when there were no building permits, inspections, or seismic standards.

Loss Potential

Property losses were estimated through the Level 2 Hazus-MH analysis for the 100-year and 500-year earthquakes and the three scenario events. Table 10 -37 through Table 10 -39 show the results for two types of property loss (and the total of the two):

- Structural loss, representing damage to building structures
- Non-structural loss, representing the value of lost contents.

**TABLE 10-36.
AGE OF STRUCTURES IN PLANNING AREA**

Time Period	Number of Current Planning Area Structures Built in Period[a]	Significance of Time Frame
Pre-1933	65,301	Before 1933, there were no explicit earthquake requirements in building codes. State law did not require local governments to have building officials or issue building permits.
1933-1940	11,929	In 1940, the first strong motion recording was made.
1941-1960	106,435	In 1960, the Structural Engineers Association of California published guidelines on recommended earthquake provisions.
1961-1975	93,346	In 1975, significant improvements were made to lateral force requirements.
1976-1994	150,504	In 1994, the Uniform Building Code was amended to include provisions for seismic safety.
1994—2009	106,698	Seismic code is currently enforced.
2010—present	11,633	Revised calculations for shear loads and reinstated thresholds removed from the 2005 IBC.
Total	**545,846**	

a. Year built information was collected from King and Snohomish County tax assessor data. Information for Pierce County was collected from Hazus inventory data at the Census block level and was estimated based on the relative distribution of year built information in King County

TABLE 10-37.
LOSS ESTIMATES FOR PROBABILISTIC EARTHQUAKES

	Estimated Loss Associated with Earthquake					
	100- Year Earthquake			500- Year Earthquake		
Jurisdiction	Structure	Contents	**Total**	Structure	Contents	**Total**
Algona	$28,447,034	$9,367,613	**$37,814,647**	$77,301,198	$24,322,771	**$101,623,969**
Auburn	$462,154,483	$160,282,043	**$622,436,526**	$1,415,743,454	$464,744,577	**$1,880,488,032**
Beaux Arts	$168,562	$45,743	**$214,304**	$1,044,067	$303,208	**$1,347,275**
Bellevue	$640,848,452	$201,922,013	**$842,770,465**	$2,566,496,520	$758,116,466	**$3,324,612,986**
Black Diamond	$3,718,136	$1,123,323	**$4,841,458**	$16,397,826	$5,046,132	**$21,443,958**
Bothell	$47,686,655	$16,009,519	**$63,696,174**	$262,737,548	$84,295,405	**$347,032,954**
Burien	$66,229,851	$21,414,579	**$87,644,430**	$364,002,299	$114,120,614	**$478,122,913**
Carnation	$42,539	$12,856	**$55,394**	$281,864	$93,759	**$375,623**
Clyde Hill	$2,743,099	$810,212	**$3,553,311**	$16,113,575	$5,133,877	**$21,247,452**
Covington	$12,880,273	$4,174,703	**$17,054,976**	$72,646,564	$23,519,893	**$96,166,457**
Des Moines	$38,475,228	$11,925,280	**$50,400,508**	$222,438,812	$66,177,913	**$288,616,724**
Duvall	$1,630,530	$504,177	**$2,134,707**	$5,971,102	$1,811,135	**$7,782,237**
Enumclaw	$38,567,959	$13,483,601	**$52,051,560**	$119,278,159	$38,579,020	**$157,857,179**
Federal Way	$114,071,243	$35,450,841	**$149,522,085**	$654,529,936	$196,456,992	**$850,986,928**
Hunts Point	$1,085,822	$319,057	**$1,404,879**	$6,541,221	$2,091,174	**$8,632,395**
Issaquah	$102,581,533	$33,161,003	**$135,742,536**	$369,935,555	$110,492,179	**$480,427,734**
Kenmore	$45,239,642	$13,006,393	**$58,246,035**	$156,005,873	$44,162,406	**$200,168,279**
Kent	$802,731,743	$289,992,114	**$1,092,723,857**	$2,396,185,649	$804,078,666	**$3,200,264,315**
Kirkland	$142,578,938	$46,237,343	**$188,816,280**	$730,179,385	$226,714,883	**$956,894,268**
Lake Forest Park	$24,573,498	$7,261,385	**$31,834,883**	$85,121,620	$24,256,690	**$109,378,310**
Maple Valley	$31,523,875	$8,765,966	**$40,289,841**	$99,588,196	$27,261,781	**$126,849,977**
Medina	$1,354,018	$403,645	**$1,757,663**	$8,039,972	$2,589,848	**$10,629,820**
Mercer Island	$16,177,204	$4,847,694	**$21,024,898**	$102,869,281	$31,584,065	**$134,453,347**
Milton	$4,217,202	$906,387	**$5,123,589**	$20,164,901	$4,164,041	**$24,328,942**
Newcastle	$7,654,196	$2,164,575	**$9,818,771**	$48,101,089	$14,407,339	**$62,508,428**
Normandy Park	$7,577,980	$2,240,173	**$9,818,153**	$46,424,547	$14,321,858	**$60,746,405**
North Bend	$18,183,467	$6,086,403	**$24,269,870**	$63,214,492	$19,337,840	**$82,552,332**
Pacific	$30,296,181	$8,713,663	**$39,009,844**	$80,128,485	$21,851,511	**$101,979,996**
Redmond	$232,685,007	$75,928,306	**$308,613,313**	$1,080,967,467	$328,831,222	**$1,409,798,689**
Renton	$406,572,748	$143,040,134	**$549,612,882**	$1,403,586,992	$460,272,342	**$1,863,859,335**
Sammamish	$52,760,902	$15,504,039	**$68,264,942**	$299,547,772	$87,520,398	**$387,068,170**
SeaTac	$155,623,933	$44,819,212	**$200,443,145**	$630,497,808	$167,386,552	**$797,884,361**
Seattle	$2,802,657,956	$961,072,154	**$3,763,730,110**	$11,215,069,752	$3,547,034,568	**$14,762,104,319**
Shoreline	$59,560,229	$18,830,291	**$78,390,520**	$357,176,854	$110,576,261	**$467,753,115**
Skykomish	$597	$185	**$782**	$4,095	$1,460	**$5,554**
Snoqualmie	$10,675,550	$3,604,971	**$14,280,521**	$47,677,353	$15,278,946	**$62,956,299**
Tukwila	$310,376,519	$119,723,909	**$430,100,428**	$1,046,914,316	$373,510,850	**$1,420,425,165**
Woodinville	$39,567,847	$13,634,733	**$53,202,580**	$215,153,720	$69,553,103	**$284,706,823**
Yarrow Point	$1,212,508	$357,543	**$1,570,051**	$7,124,863	$2,271,934	**$9,396,797**
Unincorporated	$719,803,874	$223,678,465	**$943,482,339**	$2,919,721,583	$890,818,695	**$3,810,090,279**
Total	0	0	0	0	0	0

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.3.5 for a discussion of data limitations.

TABLE 10-38.
LOSS ESTIMATES FOR SEATTLE AND SOUTH WHIDBEY FAULT SCENARIO EARTHQUAKES

	Estimated Loss Associated with Earthquake					
	Seattle Fault, M 7.2			South Whidbey M7.4		
Jurisdiction	Structure	Contents	**Total**	Structure	Contents	**Total**
Algona	$9,312,999	$3,468,595	**$12,781,594**	$2,256,845	$1,072,789	**$3,329,634**
Auburn	$278,902,902	$96,326,332	**$375,229,234**	$56,209,661	$26,777,444	**$82,987,105**
Beaux Arts	$2,361,618	$709,987	**$3,071,605**	$257,280	$92,864	**$350,145**
Bellevue	$3,434,139,472	$1,016,785,836	**$4,450,925,308**	$589,907,633	$217,484,801	**$807,392,434**
Black Diamond	$5,923,269	$2,327,217	**$8,250,486**	$767,579	$368,249	**$1,135,828**
Bothell	$51,649,438	$20,977,752	**$72,627,190**	$298,371,005	$98,375,990	**$396,746,994**
Burien	$695,692,064	$219,559,285	**$915,251,348**	$20,414,661	$9,651,441	**$30,066,102**
Carnation	$118,081	$49,977	**$168,059**	$192,109	$73,170	**$265,278**
Clyde Hill	$14,948,435	$5,328,871	**$20,277,306**	$5,352,228	$2,206,565	**$7,558,793**
Covington	$43,932,177	$16,833,097	**$60,765,274**	$3,467,376	$1,768,741	**$5,236,118**
Des Moines	$171,506,484	$54,888,620	**$226,395,104**	$8,952,242	$4,369,474	**$13,321,716**
Duvall	$1,441,045	$553,755	**$1,994,800**	$8,523,642	$2,699,870	**$11,223,512**
Enumclaw	$7,227,401	$3,348,255	**$10,575,656**	$2,605,245	$1,424,519	**$4,029,764**
Federal Way	$195,621,507	$73,320,392	**$268,941,899**	$18,826,043	$9,806,837	**$28,632,880**
Hunts Point	$6,089,105	$2,185,490	**$8,274,594**	$2,196,291	$908,421	**$3,104,712**
Issaquah	$720,990,789	$218,014,142	**$939,004,931**	$56,101,833	$20,452,250	**$76,554,083**
Kenmore	$25,548,859	$9,642,815	**$35,191,674**	$95,448,426	$29,632,334	**$125,080,759**
Kent	$1,593,538,555	$554,489,067	**$2,148,027,622**	$157,486,958	$67,723,691	**$225,210,649**
Kirkland	$314,897,434	$110,689,224	**$425,586,657**	$396,996,350	$136,191,688	**$533,188,038**
Lake Forest Park	$14,091,542	$5,417,427	**$19,508,969**	$42,430,262	$14,180,063	**$56,610,324**
Maple Valley	$56,360,481	$17,793,913	**$74,154,393**	$3,781,304	$1,627,758	**$5,409,062**
Medina	$8,230,280	$3,028,650	**$11,258,930**	$2,048,667	$822,023	**$2,870,690**
Mercer Island	$252,055,774	$77,686,233	**$329,742,007**	$19,666,773	$7,870,084	**$27,536,858**
Milton	$3,213,992	$926,353	**$4,140,345**	$630,147	$194,175	**$824,322**
Newcastle	$142,040,003	$42,469,585	**$184,509,589**	$8,009,079	$3,333,689	**$11,342,768**
Normandy Park	$68,743,162	$21,869,288	**$90,612,450**	$1,923,654	$892,479	**$2,816,133**
North Bend	$14,482,858	$5,008,343	**$19,491,201**	$4,724,690	$1,880,176	**$6,604,866**
Pacific	$9,293,567	$3,139,036	**$12,432,603**	$2,416,717	$946,355	**$3,363,071**
Redmond	$622,049,570	$197,255,876	**$819,305,445**	$580,144,955	$185,646,136	**$765,791,091**
Renton	$2,022,643,852	$652,940,003	**$2,675,583,855**	$117,991,166	$49,442,315	**$167,433,481**
Sammamish	$561,031,386	$171,233,052	**$732,264,439**	$138,125,055	$48,175,995	**$186,301,050**
SeaTac	$706,090,996	$188,194,129	**$894,285,125**	$34,980,585	$13,309,802	**$48,290,387**
Seattle	$12,313,031,567	$3,960,809,129	**$16,273,840,696**	$1,588,271,087	$641,139,232	**$2,229,410,319**
Shoreline	$77,527,321	$31,039,988	**$108,567,308**	$157,647,074	$57,091,714	**$214,738,788**
Skykomish	$433	$257	**$690**	$433	$257	**$690**
Snoqualmie	$35,639,246	$12,059,460	**$47,698,706**	$7,257,336	$2,913,100	**$10,170,437**
Tukwila	$1,292,691,431	$468,844,224	**$1,761,535,655**	$67,809,964	$31,598,954	**$99,408,918**
Woodinville	$43,353,068	$16,758,096	**$60,111,164**	$251,325,857	$79,680,559	**$331,006,416**
Yarrow Point	$6,548,732	$2,347,007	**$8,895,739**	$2,369,676	$978,430	**$3,348,106**
Unincorporated	$3,232,912,649	$1,031,014,151	**$4,263,926,800**	$1,049,421,802	$355,234,888	**$1,404,656,690**
Total	0	0	0	0	0	0

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.3.5 for a discussion of data limitations.

TABLE 10-39.
LOSS ESTIMATES FOR TACOMA FAULT SCENARIO EARTHQUAKE

Jurisdiction	Estimated Loss Associated with Earthquake		
	Tacoma Fault, M 7.1		
	Structure	Contents	**Total**
Algona	$40,512,324	$12,995,487	**$53,507,811**
Auburn	$1,247,393,305	$435,651,072	**$1,683,044,377**
Beaux Arts	$209,164	$81,917	**$291,081**
Bellevue	$254,157,710	$109,375,526	**$363,533,235**
Black Diamond	$4,807,101	$2,002,608	**$6,809,709**
Bothell	$8,302,472	$4,189,973	**$12,492,445**
Burien	$294,099,260	$98,017,858	**$392,117,118**
Carnation	$8,100	$3,875	**$11,975**
Clyde Hill	$1,809,649	$808,320	**$2,617,969**
Covington	$44,578,433	$16,781,240	**$61,359,672**
Des Moines	$513,424,310	$155,360,307	**$668,784,618**
Duvall	$193,449	$94,644	**$288,092**
Enumclaw	$12,174,444	$5,266,960	**$17,441,404**
Federal Way	$916,550,997	$267,213,881	**$1,183,764,878**
Hunts Point	$746,142	$333,091	**$1,079,233**
Issaquah	$35,569,541	$14,947,148	**$50,516,689**
Kenmore	$6,391,276	$2,765,540	**$9,156,816**
Kent	$2,541,600,283	$866,538,730	**$3,408,139,013**
Kirkland	$46,087,747	$21,834,971	**$67,922,718**
Lake Forest Park	$3,481,676	$1,515,039	**$4,996,715**
Maple Valley	$27,312,496	$9,638,681	**$36,951,177**
Medina	$914,868	$410,372	**$1,325,240**
Mercer Island	$23,621,689	$9,565,851	**$33,187,540**
Milton	$3,805,993	$1,155,397	**$4,961,391**
Newcastle	$12,769,901	$4,973,465	**$17,743,366**
Normandy Park	$87,150,788	$27,610,973	**$114,761,761**
North Bend	$3,496,593	$1,602,392	**$5,098,985**
Pacific	$30,136,839	$9,700,839	**$39,837,679**
Redmond	$77,985,476	$38,214,491	**$116,199,967**
Renton	$623,151,688	$209,993,765	**$833,145,453**
Sammamish	$30,146,607	$12,136,180	**$42,282,787**
SeaTac	$567,020,003	$155,817,792	**$722,837,795**
Seattle	$1,681,515,599	$664,668,695	**$2,346,184,294**
Shoreline	$18,909,273	$9,013,808	**$27,923,080**
Skykomish	$88	$57	**$145**
Snoqualmie	$2,970,520	$1,382,272	**$4,352,792**
Tukwila	$476,852,397	$161,727,663	**$638,580,060**
Woodinville	$8,510,708	$4,466,626	**$12,977,334**
Yarrow Point	$800,648	$357,663	**$1,158,311**
Unincorporated	$1,094,557,431	$373,765,410	0
Total	0	0	0

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.3.5 for a discussion of data limitations.

A summary of the property-related loss results is as follows:

– For a 100-year probabilistic earthquake, the estimated damage potential is $10.0 billion, or 2.03 percent of the total assessed value for the planning area.

– For a 500-year probabilistic earthquake, the estimated damage potential is $38.4 billion or 7.80 percent of the total assessed value for the planning area.

– For a 7.2-magnitude Seattle Fault event, the estimated damage potential is $38.4 billion, or 7.80 percent of the total assessed value for the planning area.

– For a 7.4-magnitude South Whidbey Fault event, the estimated damage potential is $7.9 billion, or 1.61 percent of the total assessed value for the planning area.

– For a 7.1-magnitude Tacoma Fault event, the estimated damage potential is $14.5 billion, or 2.94 percent of the total assessed value for the planning area.

The Hazus-MH analysis also estimated the amount of earthquake-caused debris in the planning area for the 100-year and 500-year earthquakes and the three scenario events, as summarized in Table 10 -40.

TABLE 10-40.
ESTIMATED EARTHQUAKE-CAUSED DEBRIS

	Debris to Be Removed (tons)
100-Year Earthquake	3,514,423
500-Year Earthquake	14,217,942
M 7.2, Seattle Fault Scenario	13,940,730
M 7.4 South Whidbey Island Fault Scenario	2,154,450
M 7.1 Tacoma Fault Scenario	5,137,030

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.3.5 for a discussion of data limitations.

10.5.3 Critical Facilities and Infrastructure

Level of Damage

Hazus-MH classifies the vulnerability of critical facilities to earthquake damage in five categories: no damage, slight damage, moderate damage, extensive damage, or complete damage. The model was used to assign a vulnerability category to each critical facility in the planning area except hazmat facilities and “other infrastructure” facilities, for which there are no established damage functions. The analysis was performed for all scenario events. Results from the 100-year probability event, the 500-year probability event and the Seattle Fault scenario are summarized in Table 10 -41 through Table 10 -43.

TABLE 10-41.
ESTIMATED DAMAGE TO CRITICAL FACILITIES FROM 100-YEAR EARTHQUAKE

	Damage Extent				
Category[a]	None	Slight	Moderate	Extensive	Complete
Medical and Health	28	425	0	0	35
Government Function	2	26	0	0	2
Protective Function	14	234	3	0	26
Schools	5	676	0	0	15
Other Critical Function	50	420	0	0	0
Bridges	1,061	0	0	0	0
Transportation	35	262	4	0	7
Water supply	263	87	3	0	1
Wastewater	216	49	0	0	1
Power	13	19	0	0	0
Communications	47	17	0	0	0
Total	0	0	0	0	0

a. Vulnerability not estimated for hazmat facilities or for “other infrastructure” facilities due to lack of established damage functions for these type facilities.

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.3.5 for a discussion of data limitations.

TABLE 10-42.
ESTIMATED DAMAGE TO CRITICAL FACILITIES FROM 500-YEAR EARTHQUAKE

	Damage Extent				
Category[a]	None	Slight	Moderate	Extensive	Complete
Medical and Health	13	9	232	90	144
Government Function	2	1	10	9	8
Protective Function	8	13	150	39	67
Schools	5	24	452	90	125
Other Critical Function	39	1	31	375	24
Bridges	905	0	0	127	29
Transportation	28	265	4	0	11
Water supply	56	20	268	4	6
Wastewater	97	67	100	0	2
Power	0	0	32	0	0
Communications	2	17	45	0	0
Total	0	0	0	0	0

a. Vulnerability not estimated for hazmat facilities or for “other infrastructure” facilities due to lack of established damage functions for these type facilities.

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.3.5 for a discussion of data limitations.

**TABLE 10-43.
ESTIMATED DAMAGE TO CRITICAL FACILITIES FROM SEATTLE FAULT SCENARIO**

	Damage Extent				
Category[a]	None	Slight	Moderate	Extensive	Complete
Medical and Health	8	200	47	20	213
Government Function	1	12	5	1	11
Protective Function	10	88	21	13	145
Schools	5	246	55	30	360
Other Critical Function	15	178	87	20	170
Bridges	977	0	0	17	67
Transportation	21	216	30	5	36
Water supply	22	100	178	49	5
Wastewater	92	72	96	5	1
Power	0	13	17	2	0
Communications	3	7	31	23	0
Total	0	0	0	0	0

a. Vulnerability not estimated for hazmat facilities or for "other infrastructure" facilities due to lack of established damage functions for these type facilities.

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.3.5 for a discussion of data limitations.

Time to Return to Functionality

Hazus-MH estimates the time to restore critical facilities to fully functional use. Results are presented as probability of being functional at specified time increments: 1, 3, 7, 14, 30 and 90 days after the event. For example, Hazus-MH may estimate that a facility has 5 percent chance of being fully functional at Day 3, and a 95-percent chance of being fully functional at Day 90. The analysis of critical facilities in the planning area was performed for all scenario earthquake events. Results from the 100-year probability event, the 500-year probability event and the Seattle Fault scenario are summarized in Table 10 -44 through Table 10 -46.

10.5.4 Environment

The environment vulnerable to earthquake hazard is the same as the environment exposed to the hazard.

10.6 FUTURE TRENDS IN DEVELOPMENT

Land use in the planning area will be directed by comprehensive plans adopted under Washington's Growth Management Act. The information in this plan provides the participating partners a tool to ensure that there is no increase in exposure in areas of high seismic risk. Development in the planning area will be regulated through building standards and performance measures so that the degree of risk will be reduced. The geologic hazard portions of the planning area are regulated under each jurisdiction's critical areas ordinances. The International Building Code establishes provisions to address seismic risk.

TABLE 10-44.
FUNCTIONALITY OF CRITICAL FACILITIES FOR 100-YEAR EARTHQUAKE

	# of Critical Facilities	Probability of Being Fully Functional (%)[a]					
		at Day 1	at Day 3	at Day 7	at Day 14	at Day 30	at Day 90
Medical and Health	488	9.5	10.7	60.2	61.5	82.7	87.5
Government Function	30	10	11.2	60.7	61.9	83.3	88.1
Protective Function	277	9.4	10.6	61.7	63	83.6	88.1
Schools	696	7.6	8.9	64.8	66.2	86.8	91
Other Critical Function	470	12.1	13.3	63.3	64.5	87.3	92.2
Bridges	1,061	96.6	97.8	98.4	98.5	98.6	99.2
Transportation	308	78	85.3	87.9	88.2	89.1	92.7
Water supply	354	74.9	94.2	97.5	98.0	98.5	99.5
Wastewater	266	67.6	87.8	95.1	95.9	96.6	98.3
Power	32	59.3	83.8	93.7	96.9	98.6	99.7
Communications	64	90.9	97.5	98.3	99	99.4	99.8
Total/Average	**4,046**	**46.9**	**54.6**	**80.1**	**81.2**	**91.3**	**94.2**

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.3.5 for a discussion of data limitations.

TABLE 10-45.
FUNCTIONALITY OF CRITICAL FACILITIES FOR 500-YEAR EARTHQUAKE

	# of Critical Facilities	Probability of Being Fully Functional (%)[a]					
		at Day 1	at Day 3	at Day 7	at Day 14	at Day 30	at Day 90
Medical and Health	488	2	2.4	20.7	21.2	46.8	59.4
Government Function	30	3	3.4	21.7	22.2	47.5	60
Protective Function	277	1.9	2.4	21.8	22.3	48.2	60.7
Schools	696	0.7	1.2	22	22.6	50	63
Other Critical Function	470	4.5	4.9	23.2	23.7	50.1	63.3
Bridges	1,061	79.4	84.2	86.7	87.2	87.8	92.1
Transportation	308	63.5	73.9	77.7	78.3	79.9	86.9
Water supply	354	43.3	74.0	84.0	86.5	90.0	96.4
Wastewater	266	38.8	68.4	84.5	86.8	90.0	96.5
Power	32	32.1	61	82.9	91.6	96	99.5
Communications	64	67.2	86.9	90.7	95.4	98	99.6
Total/Average	**4,046**	**30.6**	**42.1**	**56.0**	**58.0**	**71.3**	**79.8**

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.3.5 for a discussion of data limitations.

TABLE 10-46.
FUNCTIONALITY OF CRITICAL FACILITIES FOR SEATTLE FAULT SCENARIO

Planning Unit	# of Critical Facilities	Probability of Being Fully Functional (%)[a]					
		at Day 1	at Day 3	at Day 7	at Day 14	at Day 30	at Day 90
Medical and Health	488	2.4	2.9	24.4	24.9	45.2	54.2
Government Function	30	4.3	4.8	28.4	29	48.5	57.4
Protective Function	277	3.3	3.8	22	22.5	39.8	48.4
Schools	696	1.4	1.8	21	21.4	39.5	48.3
Other Critical Function	470	4.2	4.7	28.1	28.6	49.7	59
Bridges	1,061	80.6	84.5	86.7	87.2	87.7	91.7
Transportation	308	59.1	70	74	74.8	76.8	85.4
Water supply	354	38.7	64.6	74.6	78.1	83.6	93.5
Wastewater	266	41.3	68.9	83.0	85.3	89.3	96.6
Power	32	37.6	64.6	83.1	91.1	95.6	99.5
Communications	64	52.4	71.7	78.5	88.2	93.8	98.8
Total/Average	**4,046**	**29.6**	**40.2**	**54.9**	**57.4**	**68.1**	**75.7**

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.3.5 for a discussion of data limitations.

10.7 SCENARIO

Any seismic activity of 6.0 or greater on faults within the planning area's general region would have significant impacts throughout the planning area. Potential warning systems could give about 40 seconds' notice that a major earthquake is about to occur. This would not provide adequate time for preparation. Earthquakes of this magnitude or higher would lead to massive structural failure of property on NEHRP C, D, E, and F soils. Dams, levees and revetments built on these poor soils would likely fail, representing a loss of critical infrastructure. These events could cause secondary hazards, including landslides and mudslides that would further damage structures. River valley hydraulic-fill sediment areas are also vulnerable to slope failure, often as a result of loss of cohesion in clay-rich soils. Soil liquefaction would occur in water-saturated sands, silts or gravelly soils.

10.8 ISSUES

Important issues associated with an earthquake include but are not limited to the following:

- Over 78 percent of the planning area's building stock was built prior to 1994, when seismic provisions became uniformly applied through building code applications.
- Critical facility owners should be encouraged to create or enhance continuity of operations plans using the information on risk and vulnerability contained in this plan.
- Geotechnical standards should be established that take into account the probable impacts from earthquakes in the design and construction of new or enhanced facilities.
- Earthquakes could trigger other natural hazard events such as dam failures and landslides, which could severely impact the planning area.
- There are likely additional faults in or around King County that have not yet been discovered.

- After a major seismic event, King County is likely to experience disruptions in the flow of goods and services due to the destruction of major transportation infrastructure across the broader region.
- Citizens are expected to be self-sufficient up to three days following a major earthquake without government response agencies, utilities, private sector services and infrastructure components. Education programs are currently in place to facilitate the development of individual, family, neighborhood and business earthquake preparedness. Government alone can never make this region fully prepared. It takes individuals, families, and communities working in concert with one another to truly be prepared for disaster.
- Natural hazards have a devastating impact on businesses. Of all businesses that close following a disaster, more than 43 percent never reopen, and an additional 29 percent close for good within the next two years. The Institute of Business and Home Safety has developed “Open for Business,” which is a disaster planning toolkit to help guide businesses in preparing for and dealing with the adverse effects of natural hazards. The kit integrates protection from natural disasters into companies’ risk reduction measures to safeguard employees, customers, and the investment itself. The guide helps businesses secure human and physical resources during disasters, and helps to develop strategies to maintain business continuity before, during, and after a disaster occurs.
- King County has over 114 miles of earthen levees and revetments on soft, unstable soil. These soils are prone to liquefaction, which would severely undermine the integrity of these facilities.
- A worst-case scenario would be the occurrence of a large seismic event during a flood or high-water event. Levee failures would happen at multiple locations, increasing the impacts of the individual events.
- Earthquakes could trigger other natural hazard events such as dam failures, landslides or volcanic activity, which could severely impact district facilities.

CHAPTER 11.

FLOOD

King County prepared a comprehensive flood hazard management plan in 2006 that is the principal policy document for the King County Flood Control District. The plan was updated in 2013 and is the basis for much of the information contained in this chapter (King County, 2013c) The comprehensive flood hazard management plan is hereby linked to this regional hazard mitigation plan by reference.

DEFINITIONS

Flood—The inundation of normally dry land resulting from the rising and overflowing of a body of water.

Floodplain—The land area along the sides of a river that becomes inundated with water during a flood.

100-Year Floodplain—The area flooded by a flood that has a 1-percent chance of being equaled or exceeded each year. This is a statistical average only; a 100-year flood can occur more than once in a short period of time. The 1-percent annual chance flood is the standard used by most federal and state agencies.

Return Period—The average number of years between occurrences of a hazard (equal to the inverse of the annual likelihood of occurrence).

Riparian Zone—The area along the banks of a natural watercourse.

11.1 GENERAL BACKGROUND

A floodplain is the area adjacent to a river, creek or lake that becomes inundated during a flood. Floodplains may be broad, as when a river crosses an extensive flat landscape, or narrow, as when a river is confined in a canyon.

When floodwaters recede after a flood event, they leave behind layers of rock and mud. These gradually build up to create a new floor of the floodplain. Floodplains generally contain accumulations of sand, gravel, loam, silt, and/or clay, often extending below the bed of the stream. These sediments provide a natural filtering system, with water percolating back into the ground and replenishing groundwater. These are often important aquifers, the water drawn from them being filtered compared to the water in the stream. Fertile, flat reclaimed floodplain lands are commonly used for agriculture, commerce and residential development.

Connections between a river and its floodplain are most apparent during and after major flood events. These areas form a complex physical and biological system that not only supports a variety of natural resources but also provides natural flood and erosion control. When a river is separated from its floodplain with levees and other flood control facilities, natural, built-in benefits can be lost, altered, or significantly reduced.

11.1.1 Measuring Floods and Floodplains

The frequency and severity of flooding are measured using a discharge probability, which is the probability that a certain river discharge (flow) level will be equaled or exceeded in a given year. Flood studies use historical records to determine the probability of occurrence for the different discharge levels. The flood frequency equals 100 divided by the discharge probability. For example, the 100-year discharge has a 1-percent chance of being equaled or exceeded in any given year. The “annual flood” is the greatest flood event expected to occur in a typical year. These measurements reflect statistical averages only; it is possible for two or more floods with a 100-year or higher recurrence interval to occur in a short time period. The same flood can have different recurrence intervals at different points on a river. For example, the 1990 flood event was a 100-year flood on the Snoqualmie River at Snoqualmie but a 50-year flood on some tributaries.

The extent of flooding associated with a 1-percent annual probability of occurrence (the base flood or 100-year flood) is used as the regulatory boundary by many agencies. Also referred to as the special flood hazard area (SFHA), this boundary is a convenient tool for assessing vulnerability and risk in flood-prone communities. Many communities have maps that show the extent and likely depth of flooding for the base flood. Corresponding water-surface elevations describe the elevation of water that will result from a given discharge level, which is one of the most important factors used in estimating flood damage.

11.1.2 Floodplain Ecosystems

Floodplains can support ecosystems that are rich in plant and animal species. A floodplain can contain 100 or even 1,000 times as many species as a river. Wetting of the floodplain soil releases an immediate surge of nutrients: those left over from the last flood, and those that result from the rapid decomposition of organic matter that has accumulated since then. Microscopic organisms thrive and larger species enter a rapid breeding cycle. Opportunistic feeders (particularly birds) move in to take advantage. The production of nutrients peaks and falls away quickly, but the surge of new growth endures for some time. This makes floodplains valuable for agriculture. Species growing in floodplains are markedly different from those that grow outside floodplains. For instance, riparian trees (trees that grow in floodplains) tend to be very tolerant of root disturbance and very quick-growing compared to non-riparian trees.

11.1.3 Effects of Human Activities

Because they border water bodies, floodplains have historically been popular sites to establish settlements. Human activities tend to concentrate in floodplains for a number of reasons: water is readily available; land is fertile and suitable for farming; transportation by water is easily accessible; and land is flatter and easier to develop. But human activity in floodplains frequently interferes with the natural function of floodplains. It can affect the distribution and timing of drainage, thereby increasing flood problems. Human development can create local flooding problems by altering or confining drainage channels. This increases flood potential in two ways: it reduces the stream’s capacity to contain flows, and it increases flow rates or velocities downstream during flood events. Human activities can interface effectively with a floodplain as long as steps are taken to mitigate the activities’ adverse impacts on floodplain functions.

11.1.4 Federal Flood Programs

National Flood Insurance Program

The NFIP makes federally backed flood insurance available to homeowners, renters, and business owners in participating communities. For most participating communities, FEMA has prepared a detailed Flood Insurance Study. The study presents water surface elevations for floods of various magnitudes, including the 1-percent annual chance flood and the 0.2-percent annual chance flood (the 500-year flood). Base flood elevations and the boundaries of the 100- and 500-year floodplains are shown on Flood Insurance Rate Maps (FIRMs), which are the principle tool for identifying the extent and location of the flood hazard. FIRMs are the most detailed and consistent data source available, and for many communities they represent the minimum area of oversight under their floodplain management program.

Participants in the NFIP must, at a minimum, regulate development in floodplain areas in accordance with NFIP criteria. Before issuing a permit to build in a floodplain, participating jurisdictions must ensure that three criteria are met:

- New buildings and those undergoing substantial improvements must, at a minimum, be elevated to protect against damage by the 100-year flood.

- New floodplain development must not aggravate existing flood problems or increase damage to other properties.
- New floodplain development must exercise a reasonable and prudent effort to reduce its adverse impacts on threatened salmonid species.

In participating communities, structures permitted or built in the planning area before NFIP and related building code regulations went into effect are called “pre-FIRM” structures, and structures built afterwards are called “post-FIRM.” The insurance rate is different for the two types of structures. Communities participating in the NFIP may adopt regulations that are more stringent than those contained in 44 CFR 60.3, but not less stringent. The Washington State Building Code Act requires new construction to be elevated to 1 foot above the base flood elevation or to the design flood elevation, whichever is higher. Some communities in King County have adopted more stringent standards. For example, a 3-foot freeboard (height above the 100-year flood elevation) is standard for most structures in unincorporated King County.

The most recent preliminary FIRMs in the County are dated February 1, 2013. These maps include revisions that were made as part of the 2013 Flood Insurance Study for some parts of the County: the Sammamish River and tributaries (Bear Creek, Evans Creek, North Creek, Swamp Creek); coastal areas (Vashon Island and mainland); and the White River (from a quarter mile downstream of Highway 410 near Enumclaw to the Outlet Works at Mud Mountain Dam). These preliminary FIRMs encompass changes that were made to the November 6, 2010 Flood Insurance Study that covers all floodplains in King County (King County, 2013).

King County and 34 of the 39 incorporated areas in the County are participants in NFIP; all are currently in good standing with the provisions of the NFIP. The five jurisdictions that do not currently participate in NFIP are Beaux Arts Village, Hunts Point, Maple Valley, Newcastle and Yarrow Point. Except for Newcastle, these communities have no special flood hazard areas.

In Washington State, the Department of Ecology is the coordinating agency for floodplain management. Ecology works with FEMA and local governments by providing grants and technical assistance, evaluating community floodplain management programs, reviewing local floodplain ordinances, and participating in statewide flood hazard mitigation planning. Compliance is monitored by FEMA regional staff and by Ecology. Maintaining compliance under the NFIP is an important component of flood risk reduction. All planning partners that participate in the NFIP have identified initiatives to maintain their compliance and good standing. Planning partners who do not currently participate have identified initiatives to consider enrollment in the program.

The Community Rating System

The CRS is a voluntary program within the NFIP that encourages floodplain management activities that exceed the minimum NFIP requirements. Flood insurance premiums are discounted to reflect the reduced flood risk resulting from community actions meeting the following three goals of the CRS:

- Reduce flood losses.
- Facilitate accurate insurance rating.
- Promote awareness of flood insurance.

For participating communities, flood insurance premium rates are discounted in increments of 5 percent. For example, a Class 1 community receives a 45-percent premium discount, and a Class 9 community receives a 5-percent discount. (Class 10 communities are those that do not participate in the CRS; they receive no discount.) The CRS classes are based on 18 creditable activities in the following categories:

- Public information
- Mapping and regulations
- Flood damage reduction
- Flood preparedness.

Figure 11 -39 shows the nationwide number of CRS communities by class as of March 2014, when there were 1,296 communities receiving flood insurance premium discounts under the CRS program. Although CRS communities represent only 5 percent of the over 22,000 communities participating in the NFIP, more than 67 percent of all flood insurance policies are written in CRS communities. CRS activities can help to save lives and reduce property damage.

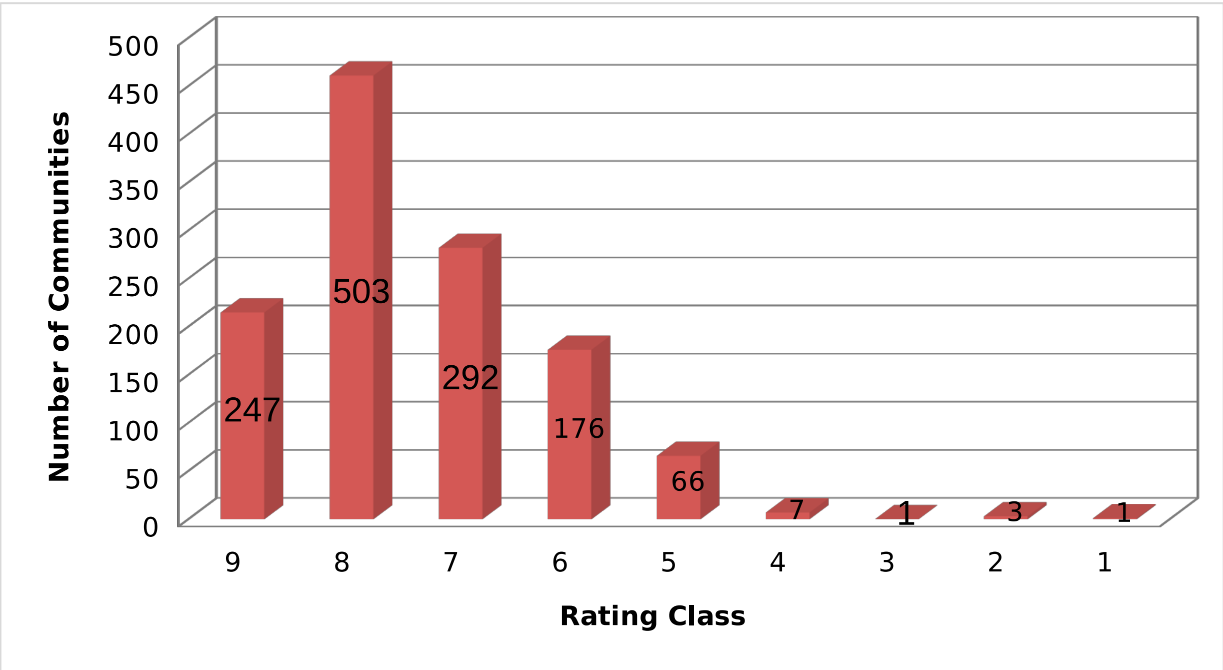


Figure 11-39. CRS Communities by Class Nationwide as of May 2014

King County and the cities of Auburn, Bellevue, Issaquah, Kent, North Bend, Renton and Snoqualmie currently participate in the CRS program. Their CRS status is summarized in Table 11 -47. The total annual savings on flood insurance premiums within the planning area is $1.33 million. Many of the mitigation actions identified in Volume 2 of this plan are creditable activities under the CRS program. Therefore successful implementation of this plan offers the potential for these communities to enhance their CRS classifications and for currently non-participating communities to join the program.

National Flood Insurance Program Biological Opinion

Background

On September 22, 2008, NOAA Fisheries issued a biological opinion that implementing the NFIP causes risk to several Endangered Species Act and Magnuson-Stevens Act listed Puget Sound salmonids and southern resident orca whales, as well as adverse modification of their habitat. NOAA Fisheries drafted the biological opinion following consultation with FEMA, in accordance with the judicial order for National Wildlife Federation v. FEMA (U.S. District Court for the Western District of Washington 2004).

TABLE 11-47.
CRS COMMUNITY STATUS IN THE PLANNING AREA

Community	NFIP Community #	CRS Entry Date	Current CRS Classification	% Premium Discount, SFHA/non-SFHA	Total Premium Savings
King County	530071	10/01/91	2	40/10	$741,962
Auburn	530073	10/01/92	5	25/10	$27,240
Bellevue	530074	10/01/92	5	25/10	$36,778
Issaquah	530079	10/01/92	5	25/10	$67,494
Kent	530080	05/01/2010	6	20/10	$214,942
North Bend	530085	10/01/1995	6	20/10	$60,690
Renton	530088	10/01/1994	6	20/10	$31,436
Snoqualmie	530090	10/01/1992	5	25/10	$149,367
Total					0

Reasonable and Prudent Alternative

Analysis focused on three elements of the NFIP—floodplain mapping, minimum floodplain management criteria, and the Community Rating System. The intent was to assess whether activities carried out under the NFIP lead to habitat changes that adversely affect listed species and their critical habitat. The biological opinion establishes seven elements of a Reasonable and Prudent Alternative to modify implementation of the NFIP in a manner that would reduce the risk to a level that may affect, but would not be likely to adversely affect, the listed species:

- **Reasonable and Prudent Alternative Element 1, Notification of Consultation Outcome**—FEMA is required to notify all communities that participate in the NFIP that development under the program could cause risk to several Endangered Species Act and Magnuson-Stevens Act listed Puget Sound salmonids and southern resident orca whales as well as adverse modification of their habitat.
- **Reasonable and Prudent Alternative Element 2, Mapping**—FEMA should only process Letters of Map Change addressing manmade alterations after determining that the alteration avoids habitat function changes or mitigates for those impacts. FEMA must also ensure that floodplain modeling incorporates on-the-ground data to increase the accuracy of maps depicting the floodplain and considers future conditions and cumulative effects from future land-use changes, including the risk of flooding behind 100-year levees.
- **Reasonable and Prudent Alternative Element 3, Floodplain Management Criteria**—This element describes land use and development criteria for development within mapped floodplains.
- **Reasonable and Prudent Alternative Element 4, Community Rating System**—FEMA will change the credit given under the CRS to incorporate habitat-based objectives. King County should benefit greatly under these changes because of the County's strong environmental protection policies, regulations, programs and projects.
- **Reasonable and Prudent Alternative Element 5, Addressing the Effects of Levee Vegetation Maintenance and Certain Types of Construction in the Floodplain**—FEMA shall not recognize levees that are certified by the U.S. Army Corps of Engineers using Public Law 84-99 vegetation standards unless it is demonstrated that the standard will not adversely affect species

or their habitat. King County and other jurisdictions in the Puget Sound region, as well as other communities on the west coast, are working with the U.S. Army Corps of Engineers to modify the Corps' levee vegetation standards for participation in the PL 84-99 program or to allow regional variances to those standards.

- **Reasonable and Prudent Alternative Element 6, Floodplain Mitigation Activities**—Any development in floodplains that degrades channel or floodplain habitat and occurs prior to full implementation of Elements 2, 3 and 5 must provide mitigation.
- **Reasonable and Prudent Alternative Element 7, Monitoring and Adaptive Management**—FEMA is required to report annually to NOAA Fisheries regarding progress on implementing the Reasonable and Prudent Alternative elements. NOAA Fisheries will determine, in coordination with FEMA, if some alternative actions or additional changes in the Reasonable and Prudent Alternative elements are needed to avoid risk and adverse modification of critical habitat.

Effect of Biological Opinion on NFIP Communities

The Reasonable and Prudent Alternative element that most significantly impacts local jurisdictions is Element 3: Floodplain Management Criteria. Under that element, FEMA must modify its floodplain management criteria as soon as possible to require NFIP communities to do the following:

- Carry out at least one of the following measures:
  - 1) Allow no development in the riparian buffer zone, identified as the greater of the channel migration zone plus a 50-foot buffer, the riparian buffer width specified by stream type, or the floodway.
    OR
  - 2) Demonstrate to FEMA that proposed riparian buffer zone development does not adversely affect salmon habitat needs.
- In addition to either 1 or 2 above, carry out at least one of the following measures:
  - 1) Prohibit development in the 100-year flood floodplain.
    OR
  - 2) Avoid, rectify or compensate for any loss of floodplain storage and fish habitat from development in the 100-year floodplain outside the riparian buffer zone. Any development allowed must use low impact development methods to minimize or avoid stormwater effects. Any indirect adverse effects must be mitigated.
    OR
  - 3) Mitigate adverse effects on fish or their habitats from structural improvements or repairs resulting in greater than 10-percent increase in structure footprint.

Local Response to Biological Opinion

More than 120 communities in the Puget Sound region are affected by FEMA's response to the biological opinion. These communities have been divided into three tiers:

- Tier One communities, which include King County, must restore fish populations to a low extinction risk status because their contribution to the abundance, diversity, spatial structure and productivity of the evolutionary significant unit or distinct population segment is critical.
- Tier Two communities may have traits that are important to evolutionary significant unit or distinct population segment viability, but their contribution is less critical.
- All other Puget Sound NFIP communities are in Tier Three.

FEMA has identified three options for NFIP communities to document compliance with the biological opinion:

- Option 1—Adopt the model ordinance developed by FEMA.
- Option 2—Complete a FEMA-developed checklist to document that local regulations and best available science will reduce risk to a level that may affect, but is not likely to adversely affect the listed species.
- Option 3—Perform a case-by-case habitat assessment for development within the mapped 100-year floodplain.

King County selected Option 2 by preparing a programmatic habitat assessment to demonstrate its compliance with the Reasonable and Prudent Alternative elements. This document provides a broad description of salmonid habitat within main stem rivers, streams and lakes, along saltwater shorelines, and in the associated 100-year floodplains. The document identifies the Endangered Species Act- or Magnuson-Stevens Act-listed salmonid species that occupy these areas, and estimates the probable biological effects resulting from development after implementing all of King County's regulatory and non-regulatory programs that are aimed at protecting and restoring these habitats. The assessment was performed at the programmatic level following guidance from FEMA's Floodplain Habitat Assessment and Mitigation: Draft Regional Guidance (FEMA 2011).

Using NOAA Fisheries' matrix of pathways and indicators to summarize the environmental parameters affecting Endangered Species Act-listed salmonids, King County assessed current conditions of all the indicators as either "not properly functioning" or "at risk" given the legacy of past land uses. King County does not anticipate additional degradation of any of these pathways and indicators; instead, they are likely on an improving trajectory due to a combined effort of regulations and non-regulatory protection and restoration actions. However, it will likely take years or decades for conditions to change to the point of being considered "restored" under NOAA Fisheries criteria. As a result, King County conservatively anticipates that the conditions are expected to be maintained. Consequently, although the biological opinion establishes a take exemption of 44.16 acres per year for King County, the assessment is that take will not occur, although there may be some minor changes in land use based on development potential in the floodplain. Take, as defined by the Endangered Species Act, means "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct."

Development in unincorporated King County is subject to a range of recently updated shoreline, critical area, clearing and grading, and stormwater regulations, all of which were developed through substantial use of best available science as required under the Washington State Shorelines and Growth Management Acts. Furthermore, as noted in the biological opinion, the County's floodplain regulations exceed the minimum requirements of the NFIP. Taken together with non-floodplain regulations and a wide range of King County programmatic actions—such as the transfer of development rights program, open space acquisitions, ecological restoration projects, and low density zoning—the floodplain regulations "minimize the effects of floodplain development on fish habitat and habitat forming processes" (NOAA Fisheries, 2008). The programmatic habitat assessment and evaluation of potential future development impacts confirms NOAA Fisheries' conclusion and further demonstrates that future development impacts may affect but are not likely to adversely affect protected species in King County's watersheds.

11.1.5 Protection of the Floodplain Environment

Protection of biological resources within floodplains is important to King County. Through comprehensive planning, critical areas ordinances, open space planning, participation in regional planning initiatives such as the Puget Sound Partnership, proactive land use regulations, and property acquisitions that have identified critical habitat to be preserved, King County established a diverse inventory of

preserve areas that maintain the natural and beneficial functions of the floodplain. These efforts have resulted in a floodplain that is predominantly free of high-density development. Key parks and preserve areas that promote the natural and beneficial functions of floodplains within the planning area are described in the following sections.

Green River Natural Resources Area

The 922-acre Green River Natural Area extends slightly north from the edge of the Enumclaw Plateau. It is about 7 miles east of Auburn along State Route 164 and roughly 6 miles northwest of Enumclaw. The natural area consists of the former Metzler, O'Grady and Green River Waterway Parks, all adjacent to the Green River. The King County Department of Natural Resources and Parks acquired the parcels between 1973 and 2003 with funds from a variety of sources.

Steep valley walls and a broad valley floor combine to create rich mosaics of plant communities that characterize the natural area. Mixed forest and deciduous upland forests cover much of the valley wall, with several forested and scrub-shrub wetlands nestled in the benches. Gallery cottonwood forests, deciduous forests, meadows (old pasture/agricultural fields), and forested, scrub-shrub, and emergent wetlands are common on the valley bottom. Native plant installation and invasive plant control enhancement efforts have occurred, along with streambed restoration projects focused on improving salmonid habitat. Several of these wetlands form the headwaters of short tributaries to the Green River. The lower reaches of the wall-based streams in this area are used for spawning by coho and chum and for rearing by chinook, coho, chum and winter steelhead. Cutthroat trout have also been reported.

Visitors to Green River Natural Area engage in activities such as walking, bicycling, nature observation and horseback riding, as well as fishing and river running activities such as rafting, tubing and kayaking. The O'Grady public access point is 500 feet north of the intersection of SE 373rd Street and 188th Avenue SE, Auburn, and the Metzler public access point is via a gravel road on the south side of SE Green Valley Road 2 miles west of its intersection with 218th Avenue. Other sections of the natural area have little use due to limited access. The site is managed for the protection of its ecological value. Public access that does not harm the ecological value of the site is accommodated.

Griffin Creek Natural Area

The Griffin Creek Natural Area covers about 46 acres of forestland on non-contiguous parcels between Carnation and Fall City. These sites are adjacent to the Carnation-Fall City Road (State Highway 203) and the Snoqualmie Valley Regional Trail. Griffin Creek, a King County Class I stream system, provides significant habitat for a number of salmonids including coho and steelhead, as well as some of the most concentrated coho spawning densities in the Snoqualmie River system. Griffin Creek Natural Area also provides low-impact passive recreation, interpretive and educational opportunities.

The northern parcel, over 27 acres of forest and former pasture lands, is bisected by the Snoqualmie Valley Regional Trail and is directly adjacent to the Archdiocese of Seattle's Camp Don Bosco. This parcel's proximity to the creek, forest lands, and regional trail will provide excellent opportunities for habitat protection as well as for continued low-impact passive recreation. The 19-acre southern group of small holdings is roughly three-quarters of a mile upstream, isolated and undeveloped.

Significant resources at Griffin Creek include:

- Griffin Creek, a King County Class I stream system, which provides significant habitat for a number of salmonids including coho and steelhead as well as some of the most concentrated coho spawning densities in the Snoqualmie River system.
- Habitat for terrestrial and aquatic wildlife, including native amphibians.

- Beaver ponds in the creek's main stem.
- Opportunities for the restoration of natural floodplain features as well as enhancement of in-stream and riparian habitats.
- Natural terraced topography that provides varied levels of public access and potential for restoration.
- Passive recreational, interpretive and educational opportunities adjacent to the Snoqualmie Valley Trail.

Mouth of Taylor Reach Natural Area

Mouth of Taylor Reach Natural Area consists of nearly 8 acres of open space at the mouth of Taylor Creek in unincorporated King County, approximately 5 miles southeast of Renton and 1.5 miles north of Maple Valley. The properties were acquired as part of the Cedar River Legacy program to protect and restore habitat. The primary restoration goal of the Mouth of Taylor Reach Natural Area is to establish a better connection between the channel and the floodplain. The Lower Cedar River Basin Plan, the Flood Hazard Reduction Plan, and the Water Resource Inventory Area 8 Draft Plan Framework and Preliminary Actions List contain a series of recommendations for levee setback and habitat restoration at or near the site. More in-depth analysis of historical river conditions, hydraulics and hydrology will be needed to determine the best approach for improving the channel-floodplain connection.

Although parking is constrained (there is no parking area, but parking may occur along the road shoulders), certain parts of the site are appropriate for low-impact passive recreation such as walking or nature observation. The primary area for use is the upland area off Maxwell Road SE. Wetlands and backwater areas that run north-south on the property limit access to the Getchman levee, which runs along the Cedar River on the southern parcels. Dense shrub vegetation may limit access on portions of the site, in particular to the northern parcels on Maxwell Road and on SE 197th Place, where there are no trails through the vegetation into the parcels.

Big Bend and Landsburg Reach Natural Areas

Big Bend and Landsburg Reach Natural Areas are both located in the Landsburg Reach of the Cedar River, from River Mile 19.6 to River Mile 21.2. Big Bend consists of three parcels (96 acres) and Landsburg Reach Natural Area consists of nine parcels (24 acres). The sites are about a mile east of Maple Valley, near the Cedar River Watershed's western boundary at Landsburg Road SE. Portions of the sites are adjacent to the King County Cedar River Regional Trail, as well as to City of Seattle's Cedar River Pipeline Road, which is also used as a trail.

The sites span both sides of the Cedar River. The Walsh Lake Diversion Ditch flows through Big Bend Natural Area, and other side channels and valley floor wetlands occur on the natural area. This reach of the Cedar River contains high-bank bluffs noted for their contribution of gravel to the river. The sites support mixed coniferous/deciduous second-growth forest relatively mature in age, along with stands predominated by coniferous, deciduous, or wetland vegetation. Invasive vegetation is present particularly along disturbed portions of the Cedar River channel.

Pedestrians, bicyclists, and equestrians traveling the Cedar River Trail pass through Big Bend Natural Area along the regional trail corridor, to or from the trailhead parking a mile east at Landsburg Road SE. There are no other parking areas for these natural areas. The natural area itself (outside the Cedar River Trail) is primarily used by pedestrians and equestrians, who follow the informal trails extending from the Cedar River Trail. The riverfront is also used seasonally by boaters and fishermen. Landsburg Reach Natural Area supports little public use except for trail connections between nearby Danville/Georgetown

trails and the Cedar River Pipeline Road. The Backcountry Horsemen and the Friends of Rock Creek Valley are key community partners at these sites, contributing significant time and energy to observing site and trail conditions, picking up litter, and other activities related to trails at the site.

Carnation Marsh Natural Area

The Carnation Marsh Natural Area is a 67-acre portion of the 190-acre Carnation Marsh wetland system along the Snoqualmie River. In 1992, King County received funds from an Aquatic Lands Enhancement Account grant to purchase the natural area. Carnation Marsh is rated as a Class 1 wetland in the King County Wetland Inventory. The marsh has direct hydrologic connection to the Snoqualmie River and provides significant storage for floodwaters. It is characterized by an abundance of large woody debris; a high diversity of woody vegetation, including mature trees and snags; and a complex hydrology supplied by valley floor springs, tributaries and seeps draining the west valley wall. Carnation Marsh is environmentally significant for a multitude of plant and animal species that use it for all or part of their life cycles. Carnation Marsh is 30 miles east of Seattle near the town of Carnation. The public can access this natural area for passive recreation and educational use via Highway 203 at West Snoqualmie Valley Rd. NE and NE 8th Street.

Ricardi Reach, Cedar Grove, and Jones Reach Natural Areas

Ricardi Reach Natural Area, Cedar Grove Natural Area, and Jones Reach Natural Area contain adjacent properties along the Cedar River. These natural areas are along the Ricardi and Jones Reaches of the Lower Cedar River. The sites are about 1.5 miles east of Renton’s urban growth boundary and are bounded by the Cedar River Trail and SR 169 to the south. These three natural areas contain nearly 1.25 miles of contiguous forested habitat along the Cedar River. The riparian forest and associated wetlands provide habitat for a variety of wildlife and bird species.

Ricardi Reach Natural Area is 7.45 acres and consists of three contiguous parcels on the left bank (facing downstream) of the Cedar River between RM 7.7 and RM 7.4. The site is bounded by the Cedar River Trail to the south and the Cedar River to the north. A mobile home park lies just west of the site. Ricardi Reach Natural Area contains a 6-acre forested wetland along the Cedar River, including a side channel off the main stem. The site is mostly forested, with a dense shrub understory. Vegetation and wetlands limit access points from the Cedar River Trail, though there may be small informal trails into the site. There is no parking at the site.

Cedar Grove Natural Area is a 73-acre parcel on the left bank of the river between RM 9.3 and RM 7.8, also bounded by the Cedar River Trail to the south and meander bends of the Cedar River to the north. This area contains a 30-acre forested/scrub-shrub wetland and multiple side channels that convey river flow during times of high water. It contains typical riparian red alder and black cottonwood forest, with a smaller proportion of coniferous trees and a dense shrub understory. There is no parking area (although drivers sometimes park on the highway shoulder at this site, Washington State Department of Transportation typically prohibits parking along state highway shoulders). There is one main access point on the west edge of Cedar Grove Natural Area, where a short informal trail extends from the Cedar River Trail to the water. This trail experiences regular use by pedestrians to view the river.

Jones Reach Natural Area contains just under 3 acres of land on the right bank at RM 8.9. Jones Reach Natural Area is bounded by Jones Road to the northeast and the Cedar River to the southwest. It is on the extremely steep north valley wall along the Cedar River (40-percent slopes in some places). The steep slopes and lack of parking on the road shoulder limit safe public access to this site.

Middle Fork of the Snoqualmie Natural Area

The Middle Fork Snoqualmie Natural Area consists of almost 150 acres of forested land on four parcels on the south side of the Middle Fork of the Snoqualmie River, about 9 miles east of North Bend. The natural area is served by only one road, the Lake Dorothy Road, which crosses the western edge of the area then crosses the river at a concrete bridge. The Middle Fork Snoqualmie is a King County Class I river and a shoreline of statewide significance because of its flow. Although anadromous fish do not spawn or rear above Snoqualmie Falls, the Middle Fork Snoqualmie River supports a valuable non-anadromous recreational fishery of cutthroat and rainbow trout, as well as whitefish. Although current use of the entire Middle Fork Snoqualmie Natural Area is minimal, passive recreational users and anglers access the river and small sandy beach via an old road just downstream of the concrete bridge. Significant resources and public access opportunities at the natural area include the following:

- The Middle Fork of the Snoqualmie River, a King County Class I stream and shoreline of statewide significance.
- Granite Creek, a King County Class II, non-anadromous salmonid-bearing stream.
- Numerous unnamed perennial creeks that drain to the river and beaver ponds in backwater areas.
- Deciduous forested wetlands within the floodplain.
- Habitat for terrestrial and aquatic wildlife including bear, elk, cougar, and amphibian species.
- High quality, diverse habitat for a variety of resident and migratory bird species.
- Good river viewing and relatively easy foot access to the river at a site adjacent to the Lake Dorothy Road bridge.

11.2 HAZARD PROFILE

King County's floodplains reflect a geologic past that includes large-scale tectonic and volcanic processes that occurred over tens of millions of years, a period of extensive glaciation that ended about 15,000 years ago (Booth et al. 2003), and at least one major mudflow, the Osceola Mudflow, which occurred roughly 5,700 years ago. The tectonic and volcanic processes created large-scale landforms, such as the Cascade and Olympic Mountain ranges, the Olympic Peninsula, and Puget Sound. The more recent glaciers and mudflows shaped many of the lowland surface features apparent today, including the topography and soils of King County's lowland river valleys. The Osceola Mudflow, which occurred when a flank of Mount Rainier collapsed, released sediment that filled the White River Basin to a depth of 75 feet and eventually settled in the lower Green River valley, converting it from an arm of Puget Sound to the fertile, low-gradient valley that it is today (Booth et al. 2003). These processes and events influenced the length, width, steepness, and sediment load and channel forms of King County's large rivers.

The headwaters and middle reaches of rivers in King County are typically steep and dominated by bedrock and boulders. In these areas, floodplains are often narrow or absent. When these rivers eventually reach the Puget Sound lowlands, they flatten out, deposit sediments, and form floodplains that are often broad, ecologically complex, and biologically productive.

In the relatively brief time since Euro-American settlement began in the Puget Sound basin, the region's floodplains have been altered extensively by development. Initially these changes were caused by land clearing and installation of drainage systems that supported land uses such as farming, mining, and railroad transportation. Despite the relatively small population of settlers in the region, major changes occurred at an accelerating pace, including conversion of forested and vegetated floodplains to farmland, removal of woody debris from stream and river channels, channelization and bank armoring, rerouting of major rivers, and the construction of dams for water supply, flood control, or hydropower.

These activities changed, often radically, the nature of King County rivers. The filling or disconnection of river side channels caused substantial losses of floodwater conveyance and habitat. Bank stabilization, typically using large, angular rock, reduced or eliminated natural riparian structures. Channel roughness was reduced and erosive water velocities increased. Large dams reduced peak flood flows and disrupted the natural flow of sediment and woody debris. Cumulatively, these actions changed many miles of rivers from hydraulically complex, multiple-thread or braided channels to higher-energy, flume-like, single-thread channels, sometimes in a matter of years. More recently, intensive residential, commercial and industrial land uses have come to occupy the downstream portions of King County's river valleys, exacerbating floodplain management conflicts and costs. It is in these flat, lowland floodplain areas that human development and flooding coincide, posing some of the greatest management challenges.

11.2.1 Types of Flood Related Hazards

Flooding in the planning area typically occurs after the Cascades experience large, wet and warm weather systems after winter snow pack has accumulated. Thus, most flooding in the planning area occurs during the winter months. During these flood events, river channels can be overwhelmed in hours, although water levels typically build over one to three days. Three types of flooding primarily affect King County: riverine, coastal and urban flooding.

Riverine Flooding

Riverine flooding is the overbank flooding of rivers and streams. The natural processes of riverine flooding add sediment and nutrients to fertile floodplain areas. Flooding in large river systems typically results from large-scale weather systems that generate prolonged rainfall over a wide geographic area, causing flooding in hundreds of smaller streams, which then drain into the major rivers. Shallow area flooding is a special type of riverine flooding. FEMA defines shallow flood hazards as areas that are inundated by the 100-year flood with flood depths of only 1 to 3 feet. These areas are generally flooded by low velocity sheet flows of water. Two types of flood hazards are generally associated with riverine flooding:

- **Inundation**—Inundation occurs when there is floodwater and debris flowing through an area that is not normally covered by water. Such events cause minor to sever damage, depending on the velocity and depth of flows, the duration of the flood event, the quantity of logs and other debris carried by the flows, and the amount and type of development and personal property along the floodwater's path.
- **Channel Migration**—Channel migration is erosion that results from the wearing away of banks and soils due to flowing water. This erosion, combined with sediment deposition, causes the migration or lateral movement of a river channel across a floodplain. A channel can also move by abrupt change in location, called avulsion, which can shift the channel location a large distance in as short a time as one flood event.

Urban Flooding

In urbanized areas of the County, localized or urban flooding not associated with stream overflow can occur where there are no drainage facilities to control flows or when runoff volumes exceed the design capacity of drainage facilities. As land is converted from fields or woodlands to roads and parking lots, it loses its ability to absorb rainfall. Urbanization of a watershed changes the hydrologic systems of the basin. Heavy rainfall collects and flows faster on impervious concrete and asphalt surfaces. The water moves from the clouds to the ground and then into streams at a much faster rate in urban areas. Adding these elements to the hydrological systems can result in floodwaters that rise very rapidly and peak with violent force. During periods of urban flooding, streets can become swiftly moving rivers and basements can fill with water. Storm drains often back up with vegetative debris, causing additional, localized

flooding. Urban flooding issues are generally addressed through stormwater management plans at the local level.

Coastal Flooding

Coastal flooding is the result of storm surges and tides. Maximum flood levels occur when high tides coincide with peak storm surges. The severity of coastal flooding varies with flood depths, wave effects and debris impacts. Wave pounding exerts substantial forces on structures. Frequent pounding by waves may destroy structures not designed to withstand wave forces. Wave action may also destroy structures by erosion that undermines foundations. Debris impacts can greatly increase damage as well (EMD, 2013).

11.2.2 Principal Flooding Sources

King County covers six drainage basins and coastal flood hazard areas, as described below.

South Fork Skykomish River Basin

The South Fork Skykomish River basin lies primarily in the northeast portion of King County and is a part of Water Resource Inventory Area 7. The King County portion of the South Fork Skykomish drains 234 square miles of mountainous terrain within the forest production zone and Alpine Lakes Wilderness Area. Major tributaries in King County include the Foss, Tye, Miller, and Beckler Rivers. There are no significant dams or reservoirs on the South Fork Skykomish or its tributaries. With its steep upper basin slopes in high elevation terrain forming the entire watershed, significant runoff can be delivered directly to the flood hazard management corridor along the South Fork Skykomish. Precipitation at these high elevations can generate flooding from rain-on-snow events.

Snoqualmie River Basin

The Snoqualmie River basin in northeast King County drains to the Snohomish River and ultimately to Puget Sound. It is a part of Water Resource Inventory Area 7. The watershed includes the Tolt River, the Raging River, Tokul Creek, Griffin Creek, Harris Creek, Patterson Creek and other tributaries. With the geologic segmentation of Snoqualmie Falls, the Snoqualmie River basin can be divided into two components: the Upper Snoqualmie and the Lower Snoqualmie.

Upper Snoqualmie River

There are no significant dams on the upper Snoqualmie River to regulate flood flows. All three forks of the Snoqualmie River are relatively steep and confined through most of their course upstream of the confluence area. The combination of no flood control impoundments and steep, confined upstream channels that open to lower-gradient floodplains creates widespread risk of inundation and channel migration during winter. Rain-on-snow events can have a significant effect in this unregulated system since the headwaters are in the high elevations of the Cascades.

Lower Snoqualmie River

With headwaters and much of the eastern basin in the Cascades and a drainage area of about 600 square miles at Carnation, the lower Snoqualmie River typically responds to winter rains with flood levels that rise and fall slowly and steadily. The low-gradient channel of the lower Snoqualmie meets the relatively steeper and faster-responding Skykomish River in Snohomish County, which can result in Skykomish River backwater influencing the lower Snoqualmie as far upstream as Duvall.

Sammamish River Basin

The Sammamish River originates at Lake Sammamish and drains a 240-square-mile watershed that includes 97 square miles of the Lake Sammamish basin, 50 square miles in the Bear Creek basin and 67 square miles of the combined Little Bear, North, and Swamp Creek basins. Water from the Lake Sammamish basin originally flowed into Lake Washington through the old Sammamish Slough, a widely meandering, low-gradient river bordered by extensive wetlands and floodplains. When Lake Washington was lowered by 9 feet after construction of the Lake Washington Ship Canal in 1912, property owners along the slough formed a drainage district to straighten and deepen the channel in order to reclaim the adjacent lands for agriculture. The U.S. Army Corps of Engineers completed river channelization in 1966 and constructed a low weir at the outlet of Lake Sammamish. The weir outlet slows release from Lake Sammamish during low-flow periods. During high flows, the weir is completely submerged by the river, acting as an uncontrolled spillway. The project was designed to pass approximately a 40-year springtime flood—equivalent to a 10-year winter storm—over the weir without the water surface elevation in Lake Sammamish exceeding 29.0 feet. The project has significantly reduced the frequency and severity of flooding risks around the lake and adjacent to the river.

Cedar River Basin

The Cedar River flows west and north from the Cascade Mountains into the south end of Lake Washington. The Cedar River is approximately 36 miles long from its mouth at Lake Washington in the City of Renton to Chester Morse Lake. The hydrology and hydraulics of the Cedar River basin have been substantially altered from natural conditions. The lowest mile of the river was rerouted by the U.S. Army Corps of Engineers in 1914 in order to provide additional water for operation of the locks between Lake Washington and Puget Sound. The mouth of the Cedar River, which previously drained to the Black River and subsequently the Green River and into Puget Sound, was diverted into Lake Washington through a straightened, dredged channel with rock-stabilized banks. In the upper Cedar River watershed, the City of Seattle operates three dams designed for municipal water supply and hydropower purposes:

- The rock-fill, timber-structured Crib Dam was constructed in 1903 and rebuilt as the Overflow Dike in 1987 at the outlet of what is now Chester Morse Lake.
- Masonry Dam controls storage capacity in Chester Morse Lake and the outflows used to produce hydroelectric power. The Masonry Dam was not designed or built to serve as a flood control dam, but in addition to its hydropower generation and water supply functions, it has the capacity to store up to 15,000 acre-feet of floodwater. However, flood-prone areas downstream remain vulnerable to severe flood risks.
- Eleven miles farther downstream is the Landsburg Diversion, constructed in 1899, which diverts municipal and industrial water supply for the City of Seattle.

Green River Basin

The Green/Duwamish River is a 93-mile long river system that originates in the Cascade Mountains at an approximate elevation of 4,500 feet and is entirely within King County. The headwaters are in the vicinity of Blowout Mountain and Snowshoe Butte, about 30 miles northeast of Mount Rainier. The river basin is part of Water Resource Inventory Area 9. The river flows through several cities, including Auburn, Kent, Renton, Tukwila and Seattle. The basin is divided into four subbasins: the upper watershed above Howard Hanson Dam; the middle Green; the lower Green; and the Duwamish estuary. The middle Green River runs from the outlet of the Green River Gorge at about River Mile 45 near Flaming Geyser down to Auburn at about River Mile 31. The lower Green River runs from Auburn down to the Duwamish River at River Mile 11.

Major structural flood risk reduction features along the Green River include Howard Hanson Dam in the upper watershed and the levee system that lines the riverbanks along much of the lower Green River and portions of the middle Green River. Howard Hanson Dam and the levee system combine to reduce flooding in the lower river to a fraction of its historical magnitude. The dam is designed to store over 100,000 acre-feet, converting large storm flows to a flow at the Auburn flow gage equivalent to the 2-year pre-dam event—12,000 cubic feet per second (cfs). The capacity of the leveed portion of the river is approximately 12,800 cfs, with approximately 2 feet of freeboard in most locations.

Since 1962, dam operations, in combination with the levees, have contained most major river flood events from Auburn downstream to the mouth of the Duwamish River. Prior to construction of the dam, the river exceeded the target 12,000 cfs 15 times between 1932 and 1962. It is estimated that without the dam, the flows on the Green River would have exceeded this flood threshold 17 to 22 times since 1962.

White River Basin

The White River originates in the glaciers on the northeast face of Mount Rainier. The White River drains an area of about 490 square miles, approximately 30 percent of which lies within King County. The White River flows from its headwaters to the northwest, where it is joined by its major tributaries, the Greenwater River and Boise Creek. It then turns south to join with the Puyallup River in Pierce County, which flows to its outlet in Puget Sound at Commencement Bay.

Historically, the bulk of what is now the lower White River flowed northward to the join the Green River near Auburn. By the early 1900s, legal intervention resulted in an Inter-County agreement and permanent diversion of the White River to flow south to the Stuck River and the Puyallup.

Mud Mountain Dam is a flood control dam near River Mile 30 that has had a significant effect on flooding in the White River since its completion in 1948. Puget Sound Energy’s diversion of flows since 1912 for hydropower generation through Lake Tapps near River Mile 24 lowers the overall White River flow regime, although the effect has been insignificant with regard to flood magnitudes.

Above the dam, the entire watershed is largely undeveloped, although it includes some scattered residential and commercial property around the community of Greenwater. The river then flows through the White River canyon, a deep and generally undeveloped valley on the county line, and portions of the Muckleshoot Indian Tribe Reservation. Development generally is concentrated in the downstream end of the basin, where both industrial and residential land uses are common.

With headwaters on Mount Rainier glaciers, the White River experiences flow increases from snowmelt in late summer, but not to a level of flood concern. The primary determinant for flooding in the White River is operation of Mud Mountain Dam. The river basin is part of Water Resource Inventory Area 10.

Coastal Flood Hazard Areas

Coastal areas are subject to a variety of natural processes that present significant hazards to public safety and property, including storm surge flooding, waves, erosion, rainfall and wind. Coastal flood hazards with potential to impact the sheltered waters of King County include coastal flooding and coastal erosion. Changes in sea level and climate change further increase the potential impact of these hazards. Coastal flooding results from high water and wave action produced by storm systems. Storm surges, also referred to as storm tides, can affect a number of beachfront areas in King County. Generally, storm surges are caused by an increase in the usual tide level by a combination of low atmospheric pressure and onshore winds. During a storm surge, water levels and waves may run significantly higher than the predicted tide level, and these higher waters may result in flooding and erosion.

Areas of coastline subject to wave attack are referred to as coastal high hazard zones. Factors that affect wave run-up include length of water over which wind blows, sustained wind velocity, coastal water depth, land slope and other coastline features. Much of the coastline along Des Moines is protected by a breakwater that extends north and south along the coast to protect the Des Moines Marina. The area west of this breakwater and the unprotected area north and south of the breakwater have been designated as coastal high hazard zones by FEMA. The unprotected sections of the coastline are subject to waves generated by high winds from a southwest direction across Puget Sound.

11.2.3 Past Events

On average, major floods in King County occur every two to five years. In past floods, water depths above grade have exceeded 6 feet in some residential areas. To date, major river flooding in King County has infrequently contributed to injury or loss of life; more typically, it results in property damage. There has been one documented flood-related fatality since 2006. Major flood events in King County have resulted in significant property damage. Table 11 -48 lists severe flood events in King County. The January 1990 event is considered to be the flood of record for most of the county except along the Lower Snoqualmie and Tolt Rivers.

11.2.4 Location

Approximately 7.5 percent of the County is located within mapped 100-year floodplains. Flooding in King County has been documented by gage records, high water marks, damage surveys and personal accounts. This documentation was the basis for the April 19, 2005, Flood Insurance Study that is incorporated in the currently effective FIRMs. The FIRMs are the most detailed and consistent data source available for determining flood extent. The 2005 Flood Insurance Study is the sole source of data used in this risk assessment to map the extent and location of the flood hazard, as shown in Figure 11 -40.

11.2.5 Frequency

King County has experienced 27 flooding events since 1965 that have resulted in federal disaster declarations and, on average, one episode of minor river flooding each winter. Large, damaging floods typically occur every two to five years. Urban portions of the county annually experience nuisance flooding related to drainage issues.

11.2.6 Severity

The principal factors affecting flood damage are flood depth and velocity. The deeper and faster flood flows become, the more damage they can cause. Shallow flooding with high velocities can cause as much damage as deep flooding with slow velocity. This is especially true when a channel migrates over a broad floodplain, redirecting high velocity flows and transporting debris and sediment. Flood severity is often evaluated by examining peak discharges; Table 11 -49 lists peak flows used by FEMA to map the floodplains of King County.

TABLE 11-48.
HISTORY OF FLOOD EVENTS

Date	Declaration #	Type of event	Estimated Damage
12/29/64	DR 185	Heavy rains, flooding	N/A
03/24/72	DR 328	Heavy rains, flooding	N/A

12/13/75	DR 492	Severe storms, flooding	N/A
12/10/77	DR 545	Severe storms, mudslides, flooding	N/A
12/31/79	DR 612	Storms, high tides, mudslides, flooding	N/A
01/16/86	DR 757	Severe storms, flooding	$294,117 ($616,128)
11/22/86	DR 784	Severe storms, flooding	N/A
01/06/90	DR 852	Flooding, severe storm	$5,246, 411[b]
11/09/90	DR 883	Flooding, severe storm	$3,694,824 [b]
12/20/90	DR 896	High tides, severe storm	$477,737[b]
11/07/95	DR 1079	Storms, high winds, floods	$3,031,519[b]
01/26/96	DR 1100	Severe storms, flooding	$4,226,719[b]
12/26/96	DR 1159	Severe storms, flooding, landslides and mudslides	$3,576,309[b]
03/18/97	DR 1172	Severe storms, flooding, landslides and mudslides	$1,266,446[b]
10/15/03	DR 1499	Severe storms, flooding	$863,636 ($1.0 million)[a]
11/02/06	DR 1671	Severe storms, flooding, landslides and mudslides	$5,386,323[b]
12/14/06	DR 1682	Severe Winter Storm, Landslides, and Mudslides	$15,578,717[b]
12/01/07	DR 1734	Severe storms, flooding, landslides and mudslides	$5,123,841[b]
12/12/08	DR 1825	Washington Severe Winter Storm and Record and Near Record Snow	$7,606,550[b]
02/27/09	DR 1817	Severe winter storm, flooding, landslides and mudslides	$16,444,775
01/11/11	DR 1963	Severe winter storm, flooding, landslides and mudslides	N/A
01/14/12	DR 4056	Severe winter storm, flooding, landslides and mudslides	N/A

a. Data obtained from Spatial Hazard Events and Losses Database for the United States (SHELDUS)
b. Information obtained from the 2013 King County Flood Hazard Management Plan-Update and Progress report
N/A = Information is not available

Insert FEMA Flood Map

Figure 11-40. FEMA Flood Hazard Areas

TABLE 11-49.
KING COUNTY RIVER BASIN STREAM FLOW CHARACTERISTICS

	USGS Station	River Mile	Drainage Area (square miles)	100-Year Flow (cfs)	Flood of Record Date; Peak Flow (cfs)
South Fork Skykomish River					
Gold Bar	12134500	43.0	535	119,300	11/6/2006; 129,000
Snoqualmie River Basin					
North Fork	12142000	9.2	64.0	18,000	1/7/09; 17,100[d]
Middle Fork	12141300	55.6	154.0	37,100	11/6/2006; 31,700
South Fork	12143400	17.3	41.6	11,000	11/6/2006; 8,910
Snoqualmie @ Snoqualmie.	12144500	40.0	375	79,100	11/24/1990; 78,800
Snoqualmie @ Carnation	12149000	23	603.0	91,800	1/8/09; 83,400[c]
Raging @ Fall City	12145500	2.75	30.6	6,970	11/24/1990; 6,220
North Fork Tolt	12147500	11.7	39.9	11,200	12/15/1959; 9,560
South Fork Tolt	12148000	6.8	19.7	8,720	12/15/1959; 6,500
Tolt @ Carnation	12148500	8.7	81.4	18,800	1/8/09; 17,900[c]
Sammamish River Basin					
Sammamish River @ Mouth	12122000	5.6	99.6	4,300	1/1/1997; 2,870
Issaquah Creek @ Mouth	12121600	1.2	55.6	3,960	01/09/1990; 3,200
Cedar River basin					
Cedar Falls	12116500	33.2	84.2	8,030	11/24/1990; 12,300
Landsburg	12117500	23.4	121.0	10,300	11/18/1911; 14,200
Renton	12119000	1.6	184.0	12,000	11/24/1990; 10,600
Green River Basin					
Howard Hanson Dam	12105900	63.8	221.0	12,000[a]	12/21/1960; 12,200 (pre-dam)
Auburn	12113000	32.0	399.0	12,000[a]	11/23/1959; 28,100 (pre-dam)
Tukwila	12113350	NA	440.0	12,400	01/31/1965; 12,100
White River Basin					
Buckley	12098500	27.9	401.0	12,000[b]	12/01/1933; 28,000 (pre-dam)
Auburn	12100496	6.30	464.0	15,500	02/10/1996; 15,000
Greenwater	12097500	1.10	73.5	6,7870	12/02/1977; 10,500

a. Flows regulated by Howard Hanson Dam
b. Maximum release from Mud Mountain Dam
c. Provisional USGS data

11.2.7 Warning Time

Due to the sequential pattern of meteorological conditions needed to cause serious flooding, it is unusual for a flood to occur without warning. Warning times for floods can be between 24 and 48 hours. Flash flooding can be less predictable, but potential hazard areas can be warned in advanced of potential flash flooding danger.

Due to the extended precipitation needed to cause serious flooding, it is unusual for a flood to occur without warning. King County's flood-warning program warns of impending flooding on major rivers so residents and agencies can prepare before serious flooding occurs. In most locations, the warning system provides at least 2 hours of lead-time before floodwaters reach damaging levels. King County has an extensive flood warning capability that targets the six major river basins within the County, as described below.

The Flood Warning Center

The Flood Warning Center is the center of operations for the Flood Warning Program during flood events. The flood emergency director activates the Flood Warning Center whenever a river reaches Phase II of the four-phase flow-based flood warning alert system illustrated in Figure 11 -41. At Phase III or greater, or at the flood emergency director's discretion, field inspection teams are sent out by the Flood Warning Center to monitor flood protection infrastructure and investigate potential flood risks.

Flood Alert System

Early flood warning notifications are critical in providing additional time for property owners, floodplain occupants and those responsible for their safety to respond to flood threats. The Flood Alert System was implemented to quickly and simultaneously send voice calls, text messages and emails to anyone who chooses to receive notifications. Subscribers can sign up for free flood alerts on a King County website or by phone. Messages are sent by King County staff using a software service when reliable river data is received that meets or exceeds Phase II, III and IV thresholds on individual rivers. Additionally, messages may be sent with flood-related emergency information.

The following is an example of a flood alert message:

> "The Snoqualmie River has reached flood phase 2. Minor flooding is expected in low-lying areas. More information at www.kingcounty.gov/flood or 1-800-768-7932"

Subscribers have options to receive alerts regarding six different river systems using three separate phase thresholds on multiple phone, text and email contacts. Other agencies offer emergency notifications, including the U.S. Geological Survey. King County's flood alert website provides information on various notification systems to assist the public in selecting the services that are best suited to their needs. Multiple public outreach efforts are ongoing to encourage the public to sign-up for flood alerts. Currently the system has over 5,000 subscribers.

Coordination With Other Agencies

The Flood Warning Center works closely with The King County Office of Emergency Management, the Road Services Division, local jurisdictions and other agencies to obtain and share up-to-date information about major flood risks, road closures, evacuations and other emergency services. Coordination also occurs with the U.S. Army Corps of Engineers and Seattle Public Utilities regarding dam operations.

Phase	Tolt River (near Carnation)	Snoqualmie (Sum of Forks)	Issaquah Creek (near Hobart)	Cedar River (Landsburg)	Green River (Auburn)	White River (near Buckley)
I	2,500 cfs	6,000 cfs	6.50 ft	1,800 cfs	5,000 cfs	5,000 cfs (Unless COE or NWS calls with specific info)
II	3,500 cfs	12,000 cfs	7.50 ft	2,800 cfs	7,000 cfs	8,000 cfs
III	5,000 cfs	20,000 cfs	8.50 ft	4,200 cfs	9,000 cfs	10,000 cfs
IV	8,500 cfs	38,000 cfs	9.00 ft	5,000 cfs	12,000 cfs	12,000 cfs

RECENT LARGE FLOOD PEAKS

Tolt River (near Carnation)	Snoqualmie (Sum of Forks)	Issaquah Creek (near Hobart)	Cedar River (Landsburg)	Green River (Auburn)	White River (near Buckley)
11,400 cfs 11/29/95	48,280 cfs 11/24/90	9.90 ft 11/24/90	10,800 cfs 11/24/90	11,500 cfs 11/24/90	14,100 cfs 1/9/90
11,800 cfs 12/15/99	53,500 cfs 11/6/06	9.73 ft 2/8/96	6,580 cfs 11/30/95	12,400 cfs 2/8/96	13,200 cfs 12/1/95
13,800 cfs 1/8/09	54,110 cfs 1/7/09	8.86 ft 1/8/09	7,870 cfs 1/8/09	12,200 cfs 11/7/06	11,700 cfs[1] 11/9/06 and 1/9/09

[1] Based on Corps data on flow releases from Mud Mountain Dam.

File name: 1208_2636hmpFIG413.ai wgab

Figure 11-41. King County Flood Warning Phase Threshold and Flood Peak Summary

The King County Flood Warning Center has coordinated closely with the National Weather Service for many decades. The National Weather Service Seattle Forecast Office provides weather observations and forecasts for western Washington and issues warnings for many types of hazards, including floods, severe weather, windstorms, snowstorms and fire conditions. The National Weather Service issues a statement when heavy rain is expected to cause flooding or aggravate existing flood conditions. These statements are generally issued two to three days before the potential event. Flood watches for specific areas and rivers are issued one to two days before an event. Flood warnings are issued up to one day in advance when flooding is imminent. This applies to a specific river forecast point that is expected to exceed a flood stage based on predictive computer river modeling output, including dam operation information, and to other streams and urban areas. For large storms and major floods, the National Weather Service conducts direct Internet briefings and uses follow-up phone calls to King County. National Weather Service statements and information are communicated to other government agencies and the public via NOAA Weather Radio, radio and television, the Internet, telephone recordings and media outlets.

11.3 SECONDARY HAZARDS

The main secondary hazard for flooding is bank erosion, which in some cases can be more harmful than actual flooding. This is especially true in the upper courses of rivers with steep gradients, where floodwaters may pass quickly and without much damage, but scour the banks, edging properties closer to the floodplain or causing them to fall in. Flooding is also responsible for hazards such as landslides when high flows over-saturate soils on steep slopes, causing them to fail. Hazardous materials spills are also a secondary hazard of flooding if storage tanks rupture and spill into streams, rivers or storm sewers.

11.4 EXPOSURE

The Level 2 Hazus-MH protocol was used to assess the risk and vulnerability to flooding in the planning area. The model used census data at the block level and FEMA floodplain data, which has a level of accuracy acceptable for planning purposes. Where possible, the Hazus-MH default data was enhanced using local GIS data from county, state and federal sources.

11.4.1 Population

Population counts of those living in the floodplain in the planning area were generated by analyzing census blocks that intersect with the 100-year and 500-year floodplains identified on FIRMs. Census blocks do not follow the boundaries of the floodplain. Therefore, the methodology used to generate these estimates counted census block groups whose centers are in the floodplain or where the majority of the population most likely lives in or near the floodplain. Hazus-MH estimated the number of buildings within the floodplain in each block, and then estimated the total population by multiplying the number of residential structures by the average King County household size of 2.39 persons per household.

Using this approach, it was estimated that the exposed population for the entire county is 18,197 within the 100-year floodplain (0.90 percent of the total county population) and 22,857 within the 500-year floodplain (1.13 percent of the total). For unincorporated portions of the county, it is estimated that the exposed population is 1,946 within the 100-year floodplain (0.77 percent of the total unincorporated county population) and 2,140 within the 500-year floodplain (0.85 percent of the total).

11.4.2 Property

Structures in the Floodplain

Table 11 -50 and Table 11 -51 summarize the total area and number of structures in the floodplain by municipality. The Hazus-MH model determined that there are 6,469 structures within the 100-year floodplain and 10,235 structures within the 500-year floodplain. In the 100-year floodplain, about 32 percent of these structures are in unincorporated areas. Seventy-five percent are residential, and the balance are commercial, industrial or agricultural.

Exposed Value

Table 11 -52 and Table 11 -53 summarize the estimated value of exposed buildings in the planning area. This methodology estimated $11.07 billion worth of building-and-contents exposed to the 100-year flood, representing 1.98 percent of the total assessed value of the planning area, and $19.8 billion worth of building-and-contents exposed to the 500-year flood, representing 3.54 percent of the total.

TABLE 11-50.
AREA AND STRUCTURES IN THE 100-YEAR FLOODPLAIN

	Area in Floodplain (Acres)	Number of Structures in Floodplain							
		Residential	Commercial	Industrial	Agriculture	Religion	Government	Education	**Total**
Algona	0	0	0	0	0	0	0	0	**0**
Auburn	1,472	41	85	7	0	0	0	2	**135**
Beaux Arts Village	0	0	0	0	0	0	0	0	**0**
Bellevue	1,408	128	22	1	0	0	0	0	**151**
Black Diamond	80	0	0	0	0	0	0	0	**0**
Bothell	563	12	52	5	0	0	0	1	**70**
Burien	119	80	0	0	0	1	0	0	**81**
Carnation	236	64	3	1	0	0	0	1	**69**
Clyde Hill	0	0	0	0	0	0	0	0	**0**
Covington	213	22	4	0	0	0	0	0	**26**
Des Moines	239	36	2	0	0	0	0	2	**40**
Duvall	89	0	0	0	0	0	0	0	**0**
Enumclaw	147	0	0	0	0	0	0	0	**0**
Federal Way	136	24	0	0	0	0	0	0	**24**
Hunts Point	0	0	0	0	0	0	0	0	**0**
Issaquah	484	221	40	13	0	1	0	1	**276**
Kenmore	205	42	0	0	0	0	0	0	**42**
Kent	3,611	187	463	40	13	1	6	0	**710**
Kirkland	95	0	1	0	0	0	0	0	**1**
Lake Forest Park	14	29	1	0	0	0	0	0	**30**
Maple Valley	0	0	0	0	0	0	0	0	**0**
Medina	0	0	0	0	0	0	0	0	**0**
Mercer Island	0	0	0	0	0	0	0	0	**0**
Milton	79	26	3	1	0	0	0	0	**30**
Newcastle	11	0	0	0	0	0	0	0	**0**
Normandy Park	87	25	0	0	0	0	0	0	**25**
North Bend	1,194	588	127	15	0	4	9	12	**755**
Pacific	193	137	2	0	0	1	0	0	**140**
Redmond	1,361	11	62	3	0	0	0	0	**76**
Renton	1,074	55	75	5	0	0	1	0	**136**
Sammamish	2,208	134	0	0	0	0	0	0	**134**
SeaTac	75	2	2	0	0	0	0	0	**4**
Seattle	29,234	295	83	80	0	0	8	0	**466**
Shoreline	49	14	0	0	0	0	0	0	**14**
Skykomish	110	109	12	0	0	1	4	2	**128**
Snoqualmie	2,044	547	64	6	1	7	3	13	**641**
Tukwila	661	6	25	1	0	0	0	0	**32**
Woodinville	63	0	0	0	0	0	0	0	**0**
Yarrow Point	0	0	0	0	0	0	0	0	**0**
Unincorporated	83,137	2,024	36	7	2	0	3	0	**2,072**
Total	**130,482**	**4,859**	**1,164**	**185**	**16**	**16**	**34**	**34**	**6,308**

**TABLE 11-51.
AREA AND STRUCTURES IN THE 500-YEAR FLOODPLAIN**

	Area in Floodplain	Number of Structures in Floodplain							
	(Acres)	Residential	Commercial	Industrial	Agriculture	Religion	Government	Education	**Total**
Algona	0	0	0	0	0	0	0	0	**0**
Auburn	1,959	125	146	23	0	0	0	2	**296**
Beaux Arts Village	0	0	0	0	0	0	0	0	**0**
Bellevue	1,445	127	22	1	0	0	0	0	**150**
Black Diamond	80	0	0	0	0	0	0	0	**0**
Bothell	582	14	52	5	0	0	0	1	**72**
Burien	159	227	0	0	0	1	0	0	**228**
Carnation	490	463	42	9	0	7	3	6	**530**
Clyde Hill	0	0	0	0	0	0	0	0	**0**
Covington	214	22	4	0	0	0	0	0	**26**
Des Moines	248	47	2	0	0	0	0	2	**51**
Duvall	98	0	0	1	0	0	0	0	**1**
Enumclaw	147	0	0	0	0	0	0	0	**0**
Federal Way	159	38	0	0	0	0	0	0	**38**
Hunts Point	0	0	0	0	0	0	0	0	**0**
Issaquah	862	609	190	19	1	4	5	8	**836**
Kenmore	229	47	0	0	0	0	0	0	**47**
Kent	5,065	331	793	79	15	2	8	4	**1,232**
Kirkland	95	0	1	0	0	0	0	0	**1**
Lake Forest Park	14	29	1	0	0	0	0	0	**30**
Maple Valley	0	0	0	0	0	0	0	0	**0**
Medina	0	0	0	0	0	0	0	0	**0**
Mercer Island	0	0	0	0	0	0	0	0	**0**
Milton	99	33	4	1	0	0	0	0	**38**
Newcastle	12	0	0	0	0	0	0	0	**0**
Normandy Park	90	28	0	0	0	0	0	0	**28**
North Bend	1,283	588	130	15	0	4	9	12	**758**
Pacific	281	317	4	0	0	1	0	0	**322**
Redmond	1,508	11	90	9	0	1	3	0	**114**
Renton	2,101	913	243	28	0	5	4	3	**1,196**
Sammamish	2,208	134	0	0	0	0	0	0	**134**
SeaTac	82	2	3	0	0	0	0	0	**5**
Seattle	29,440	589	106	80	0	0	10	0	**785**
Shoreline	53	16	0	0	0	0	0	0	**16**
Skykomish	111	110	12	0	0	1	4	2	**129**
Snoqualmie	2,079	548	64	6	1	7	3	13	**642**
Tukwila	686	6	30	1	0	0	0	0	**37**
Woodinville	79	1	3	0	0	0	0	0	**4**
Yarrow Point	0	0	0	0	0	0	0	0	**0**
Unincorporated	85,928	2,265	41	8	6	0	4	1	**2,325**
Total	**137,887**	**7,640**	**1,983**	**285**	**23**	**33**	**53**	**54**	**10,071**

TABLE 11-52.
VALUE OF STRUCTURES IN 100-YEAR FLOODPLAIN

	Value Exposed			% of Total
	Structure	Contents	**Total**	Assessed Value
Algona	$0	$0	$0	0.00%
Auburn	$411,707,349	$406,167,669	$817,875,017	4.55%
Beaux Arts	$0	$0	$0	0.00%
Bellevue	$177,903,677	$138,806,964	$316,710,641	0.64%
Black Diamond	$0	$0	$0	0.00%
Bothell	$362,519,629	$375,933,302	$738,452,931	14.52%
Burien	$20,878,299	$12,685,111	$33,563,410	0.37%
Carnation	$28,574,984	$21,276,841	$49,851,825	15.18%
Clyde Hill	$0	$0	$0	0.00%
Covington	$6,209,083	$4,169,400	$10,378,483	0.36%
Des Moines	$42,115,261	$22,133,285	$64,248,546	1.12%
Duvall	$0	$0	$0	0.00%
Enumclaw	$0	$0	$0	0.00%
Federal Way	$4,502,609	$2,251,305	$6,753,914	0.04%
Hunts Point	$0	$0	$0	0.00%
Issaquah	$162,812,100	$131,248,996	$294,061,096	3.07%
Kenmore	$8,179,446	$4,089,723	$12,269,169	0.31%
Kent	$2,458,097,904	$2,397,209,118	$4,855,307,022	14.63%
Kirkland	$9,403,641	$9,403,641	$18,807,282	0.08%
Lake Forest Park	$8,410,610	$4,441,048	$12,851,658	0.58%
Maple Valley	$0	$0	$0	0.00%
Medina	$0	$0	$0	0.00%
Mercer Island	$0	$0	$0	0.00%
Milton	$5,269,700	$2,634,850	$7,904,550	1.40%
Newcastle	$0	$0	$0	0.00%
Normandy Park	$5,951,156	$2,975,578	$8,926,734	0.68%
North Bend	$266,769,190	$209,843,232	$476,612,422	32.79%
Pacific	$26,210,249	$13,379,670	$39,589,919	4.78%
Redmond	$257,373,349	$251,016,037	$508,389,386	2.19%
Renton	$550,250,735	$550,245,491	$1,100,496,226	4.26%
Sammamish	$44,235,226	$22,117,613	$66,352,839	0.71%
SeaTac	$509,910	$366,251	$876,161	0.01%
Seattle	$344,329,867	$318,907,453	$663,237,320	0.31%
Shoreline	$2,902,641	$1,451,320	$4,353,961	0.04%
Skykomish	$31,323,663	$23,672,424	$54,996,086	73.59%
Snoqualmie	$224,779,632	$189,496,963	$414,276,595	18.03%
Tukwila	$140,044,318	$140,367,907	$280,412,226	2.41%
Woodinville	$0	$0	$0	0.00%
Yarrow Point	$0	$0	$0	0.00%
Unincorporated	$353,718,632	$188,865,256	$542,583,888	1.21%
Total	0	0	0	**2.33%**

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.3.5 for a discussion of data limitations.

TABLE 11-53.
VALUE OF STRUCTURES IN 500-YEAR FLOODPLAIN

	Value Exposed			% of Total Assessed Value
	Structure	Contents	**Total**	
Algona	$0	$0	$0	0.00%
Auburn	$631,703,751	$620,251,194	$1,251,954,945	10.14%
Beaux Arts	$0	$0	$0	0.00%
Bellevue	$178,329,780	$139,020,015	$317,349,796	0.65%
Black Diamond	$0	$0	$0	0.00%
Bothell	$362,519,629	$375,933,302	$738,425,931	14.53%
Burien	$55,207,842	$29,849,882	$85,057,725	0.93%
Carnation	$125,303,729	$91,359,336	$216,663,065	65.97%
Clyde Hill	$0	$0	$0	0.00%
Covington	$6,209,083	$4,169,400	$10,378,483	0.36%
Des Moines	$44,226,001	$23,188,655	$67,414,656	1.17%
Duvall	$446,448	$669,672	$1,116,120	0.10%
Enumclaw	$0	$0	$0	0.00%
Federal Way	$8,879,160	$4,439,580	$13,318,739	0.07%
Hunts Point	$0	$0	$0	0.00%
Issaquah	$573,904,868	$470,754,810	$1,044,659,678	10.90%
Kenmore	$9,394,053	$4,697,027	$14,091,080	0.35%
Kent	$3,849,872,069	$3,782,107,671	$7,631,979,740	23.00%
Kirkland	$9,403,641	$9,403,641	$18,807,282	0.08%
Lake Forest Park	$8,410,610	$4,441,048	$12,851,658	0.58%
Maple Valley	$0	$0	$0	0.00%
Medina	$0	$0	$0	0.00%
Mercer Island	$0	$0	$0	0.00%
Milton	$6,422,646	$3,211,323	$9,633,970	2.87%
Newcastle	$0	$0	$0	0.00%
Normandy Park	$6,498,278	$3,249,139	$9,747,417	0.75%
North Bend	$302,642,728	$245,716,770	$548,359,498	37.72%
Pacific	$57,953,167	$29,676,711	$87,629,878	10.56%
Redmond	$419,783,605	$413,056,189	$832,839,794	3.58%
Renton	$1,718,390,761	$1,642,153,577	$3,360,544,338	13.01%
Sammamish	$44,235,226	$22,117,613	$66,352,839	0.71%
SeaTac	$581,415	$437,756	$1,019,171	0.01%
Seattle	$495,555,561	$404,116,690	$899,672,250	0.42%
Shoreline	$3,412,544	$1,706,272	$5,118,816	0.05%
Skykomish	$31,440,884	$23,731,034	$55,171,918	73.83%
Snoqualmie	$225,647,285	$189,930,789	$415,578,074	18.09%
Tukwila	$165,016,102	$165,339,691	$330,355,794	2.84%
Woodinville	$3,313,452	$3,170,899	$6,484,352	0.14%
Yarrow Point	$0	$0	$0	0.00%
Unincorporated	$408,428,035	$220,674,791	$629,102,825	1.41%
Total	0	0	0	**3.81**

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.3.5 for a discussion of data limitations.

Land Use in the Floodplain

Some land uses, such as single-family homes, are more vulnerable to flooding than others, such as agricultural land or parks. Table 11 -54 shows the existing land use of parcels in the 100-year and 500-year floodplain, including vacant parcels and those in public/open space uses, broken down for the planning area. About 48 percent of the parcels in the 100-year floodplain are uncategorized uses, which contains many vacant, unimproved parcels and resource lands. These are favorable, lower-risk uses for the floodplain. The precise amount of the floodplain that contains vacant, developable land is not known. This would be valuable information for gauging the future development potential of the floodplain.

TABLE 11-54.
PRESENT LAND USE WITHIN THE FLOODPLAIN

	100-Year Floodplain		500-Year Floodplain	
Land Use	Area (acres)	% of Total Area	Area (acres)	% of Total Area
Agriculture	677	0.6%	677	0.6%
Church, Welfare or Religious Service	254	0.2%	276	0.2%
Commercial	6,784	6.4%	7528	6.8%
Education	505	0.5%	589	0.5%
Governmental Services	1,074	1.0%	1155	1.0%
Industrial/Manufacturing	2,850	2.7%	3175	2.9%
Medical/Dental Services	66	0.1%	108	0.1%
Mixed Use Development (Residential & Commercial)	16	0.0%	23	0.0%
Mortuary/Cemetery/Crematory	7	0.0%	12	0.0%
Nursing Home/Retirement Facility	85	0.1%	104	0.1%
Park/Open Space/Golf Course	8,596	8.1%	8,968	8.1%
Residential	28,752	27.0%	29,945	27.1%
Terminal or Marina	3,129	2.9%	3,297	3.0%
Utility/Easement/Right of Way	2,212	2.1%	2,346	2.1%
Water/Tideland/Wetland	376	0.4%	384	0.3%
Uncategorized (includes vacant and resource lands)	50,943	47.9%	52,035	47.0%
Total	0	**100%**	0	**100%**

Source: Summarized from King, Pierce and Snohomish County parcel data. Acreage covers only mapped parcels and thus excludes many rights of way and major water features.

11.4.3 Critical Facilities and Infrastructure

Critical facilities are buildings and infrastructure that must remain operable during hazard events to maintain essential services. Critical facilities and infrastructure in the 100-year and 500-year floodplains of the planning area are summarized in Table 11 -55 through Table 11 -58. Details are provided in the following sections.

**TABLE 11-55.
CRITICAL FACILITIES IN THE 100-YEAR FLOODPLAIN**

	Medical & Health Services	Government Function	Protective Function	Schools	Hazardous Materials	Other Critical Function	**Total**
Algona	0	0	0	0	0	0	**0**
Auburn	0	0	0	0	1	1	**2**
Beaux Arts Village	0	0	0	0	0	0	**0**
Bellevue	0	0	0	0	0	0	**0**
Black Diamond	0	0	0	0	0	0	**0**
Bothell	4	0	0	1	0	1	**6**
Burien	0	0	0	0	0	0	**0**
Carnation	0	0	0	1	0	0	**1**
Clyde Hill	0	0	0	0	0	0	**0**
Covington	0	0	0	0	0	0	**0**
Des Moines	0	0	0	0	0	0	**0**
Duvall	0	0	0	0	0	0	**0**
Enumclaw	0	0	0	0	0	0	**0**
Federal Way	0	0	0	0	0	0	**0**
Hunts Point	0	0	0	0	0	0	**0**
Issaquah	1	0	0	0	0	1	**2**
Kenmore	0	0	0	0	0		**0**
Kent	8	0	3	0	7	2	**20**
Kirkland	0	0	0	0	0	0	**0**
Lake Forest Park	0	0	0	0	0	0	**0**
Maple Valley	0	0	0	0	0	0	**0**
Medina	0	0	0	0	0	0	**0**
Mercer Island	0	0	0	0	0	0	**0**
Milton	0	0	0	0	0	0	**0**
Newcastle	0	0	0	0	0	0	**0**
Normandy Park	0	0	0	0	0	0	**0**
North Bend	7	0	2	2	0	2	**13**
Pacific	0	0	0	0	0	0	**0**
Redmond	1	0	0	1	0	1	**3**
Renton	3	0	0	0	0	1	**4**
Sammamish	0	0	0	0	0	0	**0**
SeaTac	0	0	0	0	0	0	**0**
Seattle	0	0	1	0	4	0	**5**
Shoreline	0	0	0	0	0	0	**0**
Skykomish	0	1	2	1	0	1	**5**
Snoqualmie	1	0	0	8	0	1	**10**
Tukwila	0	0	0	0	0	0	**0**
Woodinville	0	0	0	0	0	0	**0**
Yarrow Point	0	0	0	0	0	0	**0**
Unincorporated	0	0	0	0	0	0	**0**
Total	**25**	**1**	**8**	**14**	**12**	**11**	**71**

TABLE 11-56.
CRITICAL FACILITIES IN THE 500-YEAR FLOODPLAIN

	Medical & Health Services	Government Function	Protective Function	Schools	Hazardous Materials	Other Critical Function	**Total**
Algona	0	0	0	0	0	0	**0**
Auburn	0	0	0	0	3	1	**4**
Beaux Arts Village	0	0	0	0	0	0	**0**
Bellevue	0	0	0	0	0	0	**0**
Black Diamond	0	0	0	0	0	0	**0**
Bothell	4	0	0	1	0	1	**6**
Burien	0	0	0	0	0	0	**0**
Carnation	3	0	1	3	0	0	**7**
Clyde Hill	0	0	0	0	0	0	**0**
Covington	0	0	0	0	0	0	**0**
Des Moines	0	0	0	0	0	0	**0**
Duvall	0	0	0	0	0	0	**0**
Enumclaw	0	0	0	0	0	0	**0**
Federal Way	0	0	0	0	0	0	**0**
Hunts Point	0	0	0	0	0	0	**0**
Issaquah	4	0	2	2	1	3	**12**
Kenmore	0	0	0	0	0	0	**0**
Kent	13	0	3	2	13	2	**33**
Kirkland	0	0	0	0	0	0	**0**
Lake Forest Park	0	0	0	0	0	0	**0**
Maple Valley	0	0	0	0	0	0	**0**
Medina	0	0	0	0	0	0	**0**
Mercer Island	0	0	0	0	0	0	**0**
Milton	0	0	0	0	0	0	**0**
Newcastle	0	0	0	0	0	0	**0**
Normandy Park	0	0	0	0	0	0	**0**
North Bend	7	0	2	2	0	2	**13**
Pacific	0	0	0	0	0	0	**0**
Redmond	3	1	1	2	3	4	**14**
Renton	3	0	0	4	0	2	**9**
Sammamish	0	0	0	0	0	0	**0**
SeaTac	0	0	0	0	0	0	**0**
Seattle	0	0	1	0	4	0	**5**
Shoreline	0	0	0	0	0	0	**0**
Skykomish	0	1	2	1	0	1	**5**
Snoqualmie	1	0	0	8	0	1	**10**
Tukwila	0	0	0	0	0	0	**0**
Woodinville	0	0	0	0	0	0	**0**
Yarrow Point	0	0	0	0	0	0	**0**
Unincorporated	0	0	0	0	1	0	**1**
Total	**38**	**2**	**12**	**25**	**25**	**17**	**119**

**TABLE 11-57.
CRITICAL INFRASTRUCTURE IN 100-YEAR FLOODPLAIN**

	Bridges	Transportation	Water Supply	Wastewater	Power	Communications	Dams	**Total**
Algona	0	0	0	0	0	0	0	**0**
Auburn	5	0	0	1	0	0	0	**6**
Beaux Arts Village	0	0	0	0	0	0	0	**0**
Bellevue	2	0	0	0	0	0	0	**2**
Black Diamond	0	0	0	0	0	0	0	**0**
Bothell	5	0	0	0	0	0	0	**5**
Burien	0	0	0	0	0	0	0	**0**
Carnation	0	0	0	0	0	0	0	**0**
Clyde Hill	0	0	0	0	0	0	0	**0**
Covington	5	0	0	1	1	0	0	**7**
Des Moines	0	0	0	3	0	0	0	**3**
Duvall	0	0	0	1	0	0	0	**1**
Enumclaw	0	0	0	1	0	0	0	**1**
Federal Way	0	0	0	0	0	0	0	**0**
Hunts Point	0	0	0	0	0	0	0	**0**
Issaquah	2	0	0	0	0	0	0	**2**
Kenmore	2	0	0	0	0	0	0	**2**
Kent	10	2	0	0	1	0	0	**13**
Kirkland	1	0	0	0	0	0	0	**1**
Lake Forest Park	0	0	0	0	0	0	0	**0**
Maple Valley	0	0	0	0	0	0	0	**0**
Medina	0	0	0	0	0	0	0	**0**
Mercer Island	0	0	0	0	0	0	0	**0**
Milton	0	0	0	0	0	0	0	**0**
Newcastle	0	0	0	0	0	0	0	**0**
Normandy Park	0	0	0	0	0	0	0	**0**
North Bend	7	0	1	1	0	0	0	**9**
Pacific	0	0	0	0	0	0	0	**0**
Redmond	3	0	3	0	0	0	0	**6**
Renton	5	0	0	0	0	0	0	**5**
Sammamish	0	0	0	0	0	0	0	**0**
SeaTac	0	0	0	0	0	0	0	**0**
Seattle	11	54	0	1	0	0	0	**66**
Shoreline	1	0	0	0	0	0	0	**1**
Skykomish	2	1	1	0	0	0	0	**4**
Snoqualmie	5	0	1	5	2	0	1	**14**
Tukwila	2	1	0	0	0	0	0	**3**
Woodinville	0	0	0	0	0	0	0	**0**
Yarrow Point	0	0	0	0	0	0	0	**0**
Unincorporated	97	1	3	1	1	2	1	**106**
Total	**165**	**59**	**9**	**15**	**5**	**2**	**2**	**257**

TABLE 11-58.
CRITICAL INFRASTRUCTURE IN 500-YEAR FLOODPLAIN

	Bridges	Transportation	Water Supply	Wastewater	Power	Communications	Dams	**Total**
Algona	0	0	0	0	0	0	0	**0**
Auburn	5	0	0	3	0	0	0	**8**
Beaux Arts Village	0	0	0	0	0	0	0	**0**
Bellevue	2	0	0	0	0	0	0	**2**
Black Diamond	0	0	0	0	0	0	0	**0**
Bothell	5	0	0	0	0	0	0	**5**
Burien	0	0	0	1	0	0	0	**1**
Carnation	0	0	0	0	0	0	0	**0**
Clyde Hill	0	0	0	0	0	0	0	**0**
Covington	5	0	0	1	1	0	0	**7**
Des Moines	3	0	0	3	0	0	0	**6**
Duvall	0	0	0	1	0	0	0	**1**
Enumclaw	0	0	0	1	0	0	0	**1**
Federal Way	0	0	0	0	0	0	0	**0**
Hunts Point	0	0	0	0	0	0	0	**0**
Issaquah	4	0	0	1	0	0	0	**5**
Kenmore	2	0	0	0	0	0	0	**2**
Kent	17	2	0	0	2	0	0	**21**
Kirkland	1	0	0	0	0	0	0	**1**
Lake Forest Park	0	0	0	0	0	0	0	**0**
Maple Valley	0	0	0	0	0	0	0	**0**
Medina	0	0	0	0	0	0	0	**0**
Mercer Island	0	0	0	0	0	0	0	**0**
Milton	0	0	0	0	0	0	0	**0**
Newcastle	0	0	0	0	0	0	0	**0**
Normandy Park	0	0	0	0	0	0	0	**0**
North Bend	7	0	1	1	2	0	0	**11**
Pacific	0	0		1	0	0	0	**1**
Redmond	3	0	3	0	0	0	0	**6**
Renton	7	2	0	0	0	0	0	**9**
Sammamish	0	0	0	0	0	0	0	**0**
SeaTac	0	0	0	0	0	0	0	**0**
Seattle	11	68	0	3	1	0	0	**83**
Shoreline	1	0	0	0	0	0	0	**1**
Skykomish	2	1	1	0	2	0	0	**6**
Snoqualmie	5	0	2	6	2	0	1	**16**
Tukwila	2	1	0	0	0	0	0	**3**
Woodinville	0	0	0	0	0	0	0	**0**
Yarrow Point	0	0	0	0	0	0	0	**0**
Unincorporated	97	1	3	1	1	2	1	**106**
Total	**179**	**75**	**10**	**23**	**11**	**2**	**2**	**302**

Tier II Facilities

Tier II facilities are those that use or store materials that can harm the environment if damaged by a flood. The planning area includes 12 businesses in the 100-year floodplain and 25 businesses in the 500-year floodplain that report having Tier II hazardous materials. During a flood event, containers holding these materials can rupture and leak into the surrounding area, having a disastrous effect on the environment as well as residents.

Utilities and Infrastructure

Flood damage to infrastructure presents numerous risks. Roads or railroads that are blocked or damaged can isolate residents and can prevent access throughout the county, including for emergency service providers needing to get to vulnerable populations or to make repairs. Bridges washed out or blocked by floods or debris also can cause isolation. Floodwaters can back up drainage systems, causing localized flooding. Culverts can be blocked by debris from flood events, also causing localized urban flooding. Floodwaters can get into drinking water supplies, causing contamination. Sewer systems can be backed up, causing waste to spill into homes, neighborhoods, rivers and streams. Underground utilities can also be damaged. Dikes can fail or be overtopped, inundating the land that they protect.

Roads and Bridges

The following major roads pass through the 100-year floodplain and thus are exposed to flooding:

- Interstate 405
- Interstate 5
- Interstate 90
- State Road 167
- State Road 99
- State Road 18
- State Road 518
- State Road 520
- State Road 522

Some of these roads are built above the flood level, and others function as levees to prevent flooding. Still, in severe flood events these roads can be blocked or damaged, preventing access to some areas.

Flooding can affect bridges, which provide the only ingress and egress to some neighborhoods. There are 165 bridges in or over the 100-year floodplain and 179 bridges in or over the 500-year floodplain.

Levees

King County's flood protection system includes more than 119 miles of levees that protect lives and more than $7 billion in economic infrastructure in the county's 106,000 acres of floodplain. Most of these levees are operated and maintained by the King County Flood Control District. A detailed inventory of these facilities is provided in the 2013 King County Flood Hazard Management Plan Update. There are also levees on many smaller rivers, streams and creeks that protect small areas of land. Many of the levees are older and were built under earlier flood management goals. Many of these older levees are exposed to scouring and failure due to old age and construction methods. Existing levees in King County provide a highly variable level of service or level of protection. Flood flows contained by levees may have a recurrence interval ranging from 10 years to 100 years.

11.4.4 Environment

Flooding is a natural event, and floodplains provide many natural and beneficial functions. Nonetheless, with human development factored in, flooding can impact the environment in negative ways. Migrating fish can wash into roads or over dikes into flooded fields, with no possibility of escape. Pollution from roads, such as oil, and hazardous materials can wash into rivers and streams. During floods, these can settle onto normally dry soils, polluting them for agricultural uses. Human development such as bridge abutments and levees, and logjams from timber harvesting can increase stream bank erosion, causing rivers and streams to migrate into non-natural courses.

Many species of mammals, birds, reptiles, amphibians and fish live in King County in plant communities that are dependent upon streams, wetlands and floodplains. Changes in hydrologic conditions can result in a change in the plant community. Wildlife and fish are impacted when plant communities are eliminated or fundamentally altered to reduce habitat. Wildlife populations are limited by shelter, space, food and water. Since water supply is a major limiting factor for many animals, riparian communities are of special importance. Riparian areas are the zones along the edge of a river or stream that are influenced by or are an influence upon the water body. Human disturbance to riparian areas can limit wildlife's access to water, remove breeding or nesting sites, and eliminate suitable areas for rearing young. Wildlife rely on riparian areas and are associated with the flood hazard in the following ways:

- Mammals depend upon a supply of water for their existence. Riparian communities have a greater diversity and structure of vegetation than other upland areas. Beavers and muskrats are now recolonizing streams, wetlands and fallow farm fields, which are converted wetlands. As residences are built in rural areas, there is an increasing concern with beaver dams causing flooding of low-lying areas and abandoned farm ditches being filled in, which can lead to localized flooding.
- A great number of birds are associated with riparian areas. They swim, dive, feed along the shoreline, or snatch food from above. Puget Sound, rivers, lakes and wetlands are important feeding and resting areas for migratory and resident waterfowl. Other threatened or endangered species (such as the bald eagle or the peregrine falcon) eat prey from these riparian areas.
- Amphibians and reptiles are some of the least common forms of wildlife in riparian areas. However, some state threatened species, such as the western pond turtle and the spotted frog, are known to inhabit the waterways and wetlands.
- Fish habitat throughout the county varies widely based on natural conditions and human influence. Many ditches were dug throughout the county to make low, wet ground better for farming. As the water drained away and the wetlands were converted to farm fields, natural stream conditions were altered throughout the county. Agriculture along many rivers extends to the water's edge and smaller side channels have been tiled to drain better. Within developing areas, small streams were placed in pipes and wetland was filled in to support urban development. While salmonids prefer clear, free-flowing streams, other species like the Olympic mud-minnow inhabit the calm, backwater areas of sloughs and wetlands.

11.5 VULNERABILITY

11.5.1 Population

Vulnerable Populations

A geographic analysis of demographics using the Hazus-MH model identified populations vulnerable to the flood hazard as follows:

- **Economically Disadvantaged Populations**—An estimated 14 percent (1,805) of households within the 100-year floodplain are economically disadvantaged, defined as having household incomes of $20,000 or less.
- **Population over 65 Years Old**—An estimated 11 percent (3,388) of the population in the census blocks that intersect the 100-year floodplain are over 65 years old.
- **Population under 16 Years Old**—An estimated 21 percent (6,529) of the population within census blocks located in or near the 100-year floodplain are under 16 years of age.

Impacts on Persons and Households

Table 11 -59 summarizes estimated impacts on persons and households in the planning area for the 100-year and 500-year flood events.

TABLE 11-59.
ESTIMATED FLOOD IMPACT ON PERSONS AND HOUSEHOLDS

	Number of Displaced Households[a]	Number of Persons Requiring Short-Term Shelter
100-Year Flood	30789	24,382
500-Year Flood	43,251	35,926

a. Hazus-MH results in this table are not intended to be precise estimates of damage after a hazard event. They represent generalized estimates of damage that may occur as the result of the modeled scenario, based on the available data.

Public Health and Safety

Floods and their aftermath present the following threats to public health and safety:

- **Unsafe food—**Floodwaters contain disease-causing bacteria, dirt, oil, human and animal waste, and farm and industrial chemicals. They carry away whatever lies on the ground and upstream. Their contact with food items, including food crops in agricultural lands, can make that food unsafe to eat and hazardous to human health. Power failures caused by floods damage stored food. Refrigerated and frozen foods are affected during the outage periods, and must be carefully monitored and examined prior to consumption. Foods kept inside cardboard, plastic bags, jars, bottles, and paper packaging are subject to disposal if contaminated by floodwaters. Even though the packages do not appear to be wet, they may be unhygienic with mold contamination and deteriorate rapidly.
- **Contaminated drinking and washing water and poor sanitation—**Flooding impairs clean water sources with pollutants. Contact with the contaminants—whether through direct food intake, vector insects such as flies, unclean hands, or dirty plates and utensils—can result in waterborne illnesses and life-threatening infectious disease. The pollutants also saturate into the groundwater or can infiltrate into sanitary sewer lines through the ground. Wastewater treatment plants, if flooded and caused to malfunction, can be overloaded with polluted runoff waters and sewage beyond their disposal capacity, resulting in backflows of raw sewage to homes and low-lying grounds. Private wells can be contaminated or damaged severely by floodwaters, while private sewage disposal systems can become a cause of infection if they are broken or overflow. Unclean drinking and washing water and sanitation, coupled with lack of adequate sewage treatment, can lead to disease outbreaks.
- **Mosquitoes and animals—**Prolonged rainfall and floods provide new breeding grounds for mosquitoes—wet areas and stagnant pools—and can lead to an increase in the number of mosquito-borne diseases such as malaria and dengue and West Nile fevers. Rats and other rodents and wild animals also can carry viruses and diseases. The public should avoid such animals and should dispose of dead animals in accordance with guidelines issued by local animal control authorities. Leptospirosis—a bacterial disease associated predominantly with rats—often accompanies floods in developing countries, although the risk is low in industrialized regions unless cuts or wounds have direct contact with disease-contaminated floodwaters or animals.

- **Mold and mildew—**Excessive exposure to mold and mildew can cause flood victims—especially those with allergies and asthma—to contract upper respiratory diseases, triggering cold-like symptoms. Molds grow in as short a period as 24 to 48 hours in wet and damp areas of buildings and homes that have not been cleaned after flooding, such as water-infiltrated walls, floors, carpets, toilets and bathrooms. Very small mold spores can be easily inhaled by human bodies and, in large enough quantities, cause allergic reactions, asthma episodes, and other respiratory problems. Infants, children, elderly people and pregnant women are considered most vulnerable to mold-induced health problems.
- **Carbon monoxide poisoning—**Carbon monoxide poisoning is as a potential hazard after major floods. In the event of power outages following floods, flood victims tend to use alternative sources of fuels for heating or cooking inside enclosed or partly enclosed houses, garages or buildings without an adequate level of air ventilation. Carbon monoxide can be found in combustion fumes such as those generated by small gasoline engines, stoves, generators, lanterns, gas ranges, or the burning of charcoal or wood. Built-up carbon monoxide from these sources can poison people and animals.
- **Hazards when reentering and cleaning flooded homes and buildings—**Flooded buildings can pose significant health hazards to people entering and cleaning damaged buildings or working to restore utility service after floodwaters recede. Electrical power systems, including fallen power lines, can become hazardous. Gas leaks from pipelines or propane tanks can trigger fire and explosion. Flood debris—such as broken bottles, wood, stones and walls—may cause wounds and injuries to those removing contaminated mud and cleaning damaged buildings. Containers of hazardous chemicals, including pesticides, insecticides, fertilizers, car batteries, propane tanks and other industrial chemicals, may be hidden or buried under flood debris. A health hazard can also occur when hazardous dust and mold in ducts, fans and ventilators of air-conditioning and heating equipment are circulated through a building and inhaled by those engaged in cleanup and restoration.
- **Mental stress and fatigue—**Having experienced a devastating flood and seen loved ones lost or injured and homes damaged or destroyed, flood victims can experience long-term psychological impact. The expense and effort required to repair flood-damaged homes places severe financial and psychological burdens on the people affected, in particular the unprepared and uninsured. Post-flood recovery—especially when it becomes prolonged—can cause mental disorders, anxiety, anger, depression, lethargy, hyperactivity, sleeplessness, and, in an extreme case, suicide. Behavior changes may also occur in children such as an increase in bed-wetting and aggression. There is also a long-term concern among the affected that their homes can be flooded again in the future.

Current loss estimation models such as Hazus are not equipped to measure public health impacts such as these. The best level of mitigation for these impacts is to be aware that they can occur, educate the public on prevention, and be prepared to deal with them in responding to flood events.

11.5.2 Property

Hazus-MH calculates flood losses to structures based on flooding depth and structure type. Using historical flood insurance claim data, Hazus-MH estimates the percentage of damage to structures and their contents by applying established damage functions to an inventory. For this analysis, local data on facilities was used instead of the default inventory data provided with Hazus-MH. The analysis is summarized in Table 11 -60 and Table 11 -61 for the 100-year and 500-year flood events, respectively.

**TABLE 11-60.
LOSS ESTIMATES FOR 100-YEAR FLOOD EVENT**

	Structures Impacted[a]	Estimated Loss Associated with Flood			% of Total Assessed Value
		Structure	Contents	**Total**	
Algona	0	$0	$0	$0	0.00
Auburn	58	$7,503,762	$9,985,134	$17,488,897	0.10
Beaux Arts	0	$0	$0	$0	0.00
Bellevue	67	$2,095,740	$976,058	$3,071,798	0.01
Black Diamond	0	$0	$0	$0	0.00
Bothell	32	$20,158,177	$73,899,529	$94,057,706	1.84
Burien	56	$1,854,889	$1,294,250	$3,149,139	0.03
Carnation	24	$621,401	$386,436	$1,007,837	0.31
Clyde Hill	0	$0	$0	$0	0.00
Covington	12	$195,286	$123,303	$318,589	0.01
Des Moines	26	$6,689,850	$4,029,779	$10,719,629	0.19
Duvall	0	$0	$0	$0	0.00
Enumclaw	0	$0	$0	$0	0.00
Federal Way	22	$750,623	$417,817	$1,168,439	0.01
Hunts Point	0	$0	$0	$0	0.00
Issaquah	116	$5,232,104	$5,240,025	$10,472,129	0.11
Kenmore	10	$176,420	$76,108	$252,527	0.01
Kent	596	$156,011,992	$502,555,169	$658,567,161	1.98
Kirkland	1	$94,036	$188,073	$282,109	0.00
Lake Forest Park	30	$1,577,002	$1,072,523	$2,649,525	0.12
Maple Valley	0	$0	$0	$0	0.00
Medina	0	$0	$0	$0	0.00
Mercer Island	0	$0	$0	$0	0.00
Milton	17	$199,565	$82,654	$282,218	0.07
Newcastle	0	$0	$0	$0	0.00
Normandy Park	21	$436,161	$182,895	$619,056	0.05
North Bend	404	$16,164,488	$24,689,852	$40,854,339	2.81
Pacific	111	$1,936,208	$788,329	$2,724,536	0.33
Redmond	28	$951,468	$2,950,857	$3,902,324	0.02
Renton	78	$29,802,495	$95,059,777	$124,862,272	0.48
Sammamish	47	$1,088,099	$463,054	$1,551,153	0.02
SeaTac	2	$6,735	$7,043	$13,778	0.00
Seattle	360	$42,472,552	$47,231,893	$89,704,445	0.04
Shoreline	6	$267,268	$128,517	$395,784	0.00
Skykomish	68	$1,888,564	$5,193,194	$7,081,758	9.48
Snoqualmie	468	$23,560,747	$47,908,382	$71,469,129	3.11
Tukwila	28	$17,950,090	$64,705,994	$82,656,084	0.71
Woodinville	0	$0	$0	$0	0.00
Yarrow Point	0	$0	$0	$0	0.00
Unincorporated	1,206	$31,459,320	$19,211,450	**$50,670,771**	0.11
Total	0	0	0	0	**0.26**

a. Impacted structures are those structures with finished floor elevations below the 100-year water surface elevation. These structures are the most likely to receive significant damage in a 100-year flood event

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.3.5 for a discussion of data limitations.

TABLE 11-61.
LOSS ESTIMATES FOR 500-YEAR FLOOD EVENT

	Structures Impacted[a]	Estimated Loss Associated with Flood			% of Total Assessed Value
		Structure	Contents	**Total**	
Algona	0	$0	$0	$0	0.00%
Auburn	135	$10,190,074	$30,467,915	$40,657,989	0.22%
Beaux Arts	0	$0	$0	$0	0.00%
Bellevue	135	$45,274,716	$54,053,230	$99,327,946	0.20%
Black Diamond	0	$0	$0	$0	0.00%
Bothell	52	$25,504,524	$78,148,137	$103,652,661	2.02%
Burien	199	$23,010,516	$13,490,836	$36,501,352	0.40%
Carnation	466	$12,207,072	$14,710,931	$26,918,004	8.20%
Clyde Hill	0	$0	$0	$0	0.00%
Covington	25	$1,861,207	$1,131,300	$2,992,507	0.11%
Des Moines	31	$15,844,654	$10,821,901	$26,666,555	0.46%
Duvall	0	$0	$0	$0	0.00%
Enumclaw	0	$0	$0	$0	0.00%
Federal Way	30	$3,348,463	$1,755,706	$5,104,169	0.03%
Hunts Point	0	$0	$0	$0	0.00%
Issaquah	155	$19,652,486	$31,685,737	$51,338,223	0.54%
Kenmore	10	$1,231,726	$766,356	$1,998,081	0.05%
Kent	596	$156,011,992	$502,555,169	$658,567,161	1.98%
Kirkland	1	$1,411,387	$4,613,670	$6,025,057	0.03%
Lake Forest Park	28	$1,441,823	$891,205	$2,333,028	0.11%
Maple Valley	0	$0	$0	$0	0.00%
Medina	0	$0	$0	$0	0.00%
Mercer Island	0	$0	$0	$0	0.00%
Milton	23	$396,766	$210,166	$606,932	0.28%
Newcastle	0	$0	$0	$0	0.00%
Normandy Park	21	$1,772,968	$1,052,160	$2,825,127	0.22%
North Bend	596	$20,205,860	$26,587,391	$46,793,250	3.22%
Pacific	258	$2,129,830	$906,578	$3,036,408	0.37%
Redmond	117	$25,200,967	$80,007,513	$105,208,480	0.45%
Renton	199	$31,888,670	$98,862,168	$130,750,838	0.51%
Sammamish	119	$12,254,163	$7,645,982	$19,900,145	0.21%
SeaTac	5	$47,452	$90,231	$137,683	0.00%
Seattle	502	$33,280,783	$63,233,488	$96,514,271	0.05%
Shoreline	8	$1,275,211	$581,675	$1,856,886	0.02%
Skykomish	127	$4,794,612	$8,673,871	$13,468,484	18.02%
Snoqualmie	371	$51,362,428	$159,055,828	$210,418,256	9.16%
Tukwila	56	$21,181,106	$80,882,493	$102,063,599	0.88%
Woodinville	2	$505,498	$1,510,471	$2,015,969	0.04%
Yarrow Point	0	$0	$0	$0	0.00%
Unincorporated	1,921	$85,185,560	$56,198,221	**$141,338,781**	0.32%
Total	0	0	0	0	**0.35%**

a. Impacted structures are those structures with finished floor elevations below the 100-year water surface elevation. These structures are the most likely to receive significant damage in a 100-year flood event

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.3.5 for a discussion of data limitations.

It is estimated that there would be up to $1.28 billion of flood loss from a 100-year flood event in the planning area. This represents 11.57 percent of the total exposure to the 100-year flood and 0.25 percent of the total assessed value for the planning area. It is estimated that there would be $1.16 billion of flood loss from a 500-year flood event, representing 5.87 percent of the total exposure to a 500-year flood event and 0.21 percent of the total assessed value.

National Flood Insurance Program

Table 11 -62 lists flood insurance statistics for the jurisdictions in the planning area that participate in the NFIP. In these jurisdictions, 8,801 flood insurance policies provide $2.5 billion in insurance coverage. According to FEMA, 2,823 flood insurance claims were paid between January 1, 1978 and December 31, 2010, for a total of $49.5 million, an average of $17,551 per claim.

Properties constructed after a FIRM has been adopted are eligible for reduced flood insurance rates. Such structures are less vulnerable to flooding since they were constructed after regulations and codes were adopted to decrease vulnerability. Properties built before a FIRM is adopted are more vulnerable to flooding because they do not meet code or are located in hazardous areas. The first FIRMs in King County were available in 1978.

Repetitive Loss

A repetitive loss property is defined by FEMA as an NFIP-insured property that has experienced any of the following since 1978, regardless of any changes in ownership:

- Four or more paid losses in excess of $1,000
- Two paid losses in excess of $1,000 within any rolling 10-year period
- Three or more paid losses that equal or exceed the current value of the insured property.

Repetitive loss properties make up only 1 to 2 percent of flood insurance policies in force nationally, yet they account for 40 percent of the nation’s flood insurance claim payments. The government has instituted programs encouraging communities to identify and mitigate the causes of repetitive losses. A recent report on repetitive losses by the National Wildlife Federation found that 20 percent of these properties are outside any mapped 100-year floodplain. The key identifiers for repetitive loss properties are the existence of flood insurance policies and claims paid by the policies. With the potential for minor flood events every year and major events every two to five years, the County and its planning partners consider all of the mapped floodplain areas as susceptible to repetitive flooding.

A repetitive loss area is the portion of a floodplain holding structures that FEMA has identified as meeting the definition of repetitive loss. The CRS requires participating communities to identify repetitive loss areas. Identifying the broader area helps to identify structures that are at risk but are not on FEMA’s list of repetitive loss structures because no flood insurance policy was in force at the time of loss. Figure 11 -42 shows the repetitive loss areas in King County.

FEMA has identified 313 repetitive loss properties in the planning area as of January 31, 2014. The breakdown of the properties by jurisdiction is presented in Table 11 -63. Of the identified properties, 306 were able to be geocoded for spatial analysis. A review of properties on this list indicated that 286 are located in the 100-year floodplain and three are outside the 100-year floodplain but within the 500-year floodplain. Of all listed properties, 95.5 percent are residential.

TABLE 11-62. FLOOD INSURANCE STATISTICS

Jurisdiction	Date of Entry Initial FIRM Effective Date	# of Flood Insurance Policies as of 12/31/2013	Insurance In Force	Total Annual Premium	Claims, 11/1978 to 12/31/2013	Value of Claims paid, 11/1978 to 12/31/2013
Algona	05/16/95	53	14,812,000	21,769	0	0
Auburn	06/01/81	681	202,795,500	426,445	11	43,341.02
Bellevue	12/01/78	259	69,242,800	132,524	46	539,887.08
Black Diamond	10/30/79	1	350,000	460	0	0
Bothell	06/01/82	49	17,179,600	54,496	10	33,665.27
Burien	09/30/94	84	21,180,700	96,594	18	84,053.59
Carnation	03/04/80	108	30,572,100	72,767	26	786,646.68
Clyde Hill	05/16/95	8	2,800,000	3,488	0	0
Covington	04/19/01	6	1,772,200	7,013	0	0
Des Moines	05/15/80	20	5,156,000	21,114	4	211,934.98
Duvall	06/04/80	7	2,222,400	8,241	4	146,511.59
Enumclaw	09/29/89	10	2,860,000	8,283	3	69,500.65
Federal Way	05/16/95	48	14,451,000	29,717	3	18,172.55
Issaquah	05/01/80	230	58,770,700	217,807	148	3,974,505.06
Kenmore	11/13/98	4	1,051,300	5,345	1	14,697.30
Kent	04/01/81	1181	431,273,700	1,224,710	31	129,404.88
Kirkland	06/15/81	65	15,170,000	26,132	7	44,518.84
Lake Forest Park	02/15/80	9	2,675,000	7,261	4	1,886.44
Medina	05/16/95	8	2,800,000	3,440	0	0
Mercer Island	05/16/95	41	11,826,000	19,725	5	6,952.20
Milton	02/17/82	12	2,210,400	10,563	4	70,379.73
Normandy Park	11/02/77	23	6,282,000	22,951	7	13,978.43
North Bend	08/01/84	578	141,754,100	642,665	78	985,053.86
Pacific	12/02/80	162	49,796,700	78,229	26	437,038.95
Redmond	02/01/79	605	158,484,200	313,492	10	21,542.88
Renton	05/05/81	271	104,678,700	293,749	17	84,974.92
Sammamish	11/18/99	4	1,198,700	6,780	2	41,996.22
SeaTac	09/30/94	13	3,764,000	5,044	1	1,319.24
Seattle	07/19/77	840	225,234,200	481,145	201	2,020,690.16
Shoreline	03/04/97	1	350,000	414	1	4,021.74
Skykomish	07/02/81	39	8,009,700	50,616	18	304,215.24
Snoqualmie	07/05/84	509	120,403,000	635,009	952	17,994,157.86
Tukwila	08/03/81	256	119,042,900	404,672	3	1,309.89
Woodinville	05/16/95	34	11,386,900	48,067	0	0
Unincorporated	09/29/78	2582	668,274,400	1,981,647	1,182	21,459,886.16
Total		0	0	0	0	0

Insert Repetitive Loss Areas Map

Figure 11-42. Planning Area Repetitive Loss Areas

**TABLE 11-63.
REPETITIVE LOSS PROPERTIES**

	Current Repetitive Loss Structures							Properties Shown to Have Been Mitigated	**Total**
	Residential	Commercial	Industrial	Agriculture	Religion	Government	Education		
Bellevue	1	0	0	0	0	0	0	1	1
Burien	5	0	0	0	0	1	0	0	6
Issaquah	12	2	0	0	0	0	0	1	14
Kenmore	2	0	0	0	0	0	0	0	2
Kent	1	0	0	0	0	0	0	0	1
Kirkland	1	0	0	0	0	0	0	0	1
Lake Forest Park	1	0	0	0	0	0	0	0	1
Mercer Island	1	0	0	0	0	0	0	0	1
Normandy Park	1	0	0	0	0	0	0	0	1
North Bend	3	1	0	0	0	0	0	0	4
Seattle	11	1	1	0	0	0	0	0	13
Shoreline	1	0	0	0	0	0	0	1	1
Skykomish	1	0	0	0	0	0	0	0	1
Snoqualmie	151	4	0	0	1	0	0	43	156
Woodinville	2	0	0	0	0	0	0	0	2
Unincorporated	105	2	1	0	0	0	0	**3**	**108**
Total	**299**	**10**	**2**	**0**	**1**	**1**	**0**	0	0

Seventeen identified repetitive loss properties are outside the County’s special flood hazard area. These appear to have minor flooding issues associated with localized stormwater flooding that does not cause repetitive flooding of any structures other than those listed on the repetitive loss list. The average claim paid for these properties was $11,595, which is typical of shallow flood damage associated with stormwater issues.

11.5.3 Critical Facilities and Infrastructure

Hazus-MH was used to estimate potential flood damage to critical facilities exposed to the flood risk. Using depth/damage function curves to estimate the percent of damage to the building and contents of critical facilities, Hazus-MH correlates these estimates into an estimate of functional down-time (the estimated time it will take to restore a facility to 100 percent of its functionality). This helps to gauge how long the planning area could have limited usage of facilities deemed critical to flood response and recovery. The Hazus critical facility results are as follows:

- **100-year flood event**—On average, critical facilities would receive 5.12 percent damage to the structure and 8.28 percent damage to the contents during a 100-year flood event. The estimated time to restore these facilities to 100 percent of their functionality is 424 days.
- **500-year flood event**—A 500-year flood event would damage the structures an average of 5.63 percent and the contents an average 13.31 percent. The estimated time to restore these facilities to 100 percent of their functionality after a 500-year event is 438 days.

11.5.4 Environment

The environment vulnerable to flood hazard is the same as the environment exposed to the hazard. Loss estimation platforms such as Hazus-MH are not currently equipped to measure environmental impacts of flood hazards. The best gauge of vulnerability of the environment would be a review of damage from past flood events. Loss data that segregates damage to the environment was not available at the time of this plan. Capturing this data from future events could be beneficial in measuring the vulnerability of the environment for future updates.

11.6 FUTURE TRENDS

Several comprehensive plans guide development in the planning area. The County's Comprehensive Plan sets goals, objectives, policies and actions for frequently flooded areas. The County has developed several plans and initiatives to promote healthy watersheds and to manage stormwater runoff by directing future development away from flood risk areas. King County's critical areas regulations regulate how development and redevelopment can safely occur on lands that contain critical areas. Additionally, King County participates in the NFIP and has adopted flood damage prevention regulations in response to its requirements. King County and all planning partners that participate in the NFIP have committed to maintaining their good standing under the NFIP through initiatives identified in this plan.

King County's population increased an average of 1.07 percent per year between 2000 and 2010, a total of 10.05 percent. It is estimated that King County's population will increase by an additional 20 percent by 2040. County plans and regulations will reduce the impacts of this future growth on floodplains and critical areas and lessen the impacts of flooding on future development. State-mandated growth management, stormwater management and critical areas regulation has been effective in limiting an increase in flood risk throughout Washington. Development trends by basin are described below.

South Fork Skykomish River Basin

The South Fork Skykomish River basin has maintained a rural land use environment. Significant development has not and likely will not occur in this area because a large portion of it is protected wilderness area and forest production areas. Future land use is projected to be similar to current land use. Only a small increase in households is projected for the period through 2022 (King County 2004).

Snoqualmie River Basin

Much of the urbanization in the Snoqualmie River basin is in incorporated areas. While urban areas constitute only about 3 percent of the basin, they make up a significant portion of some subbasins, including the main stem Snoqualmie (15 percent), Patterson Creek (10 percent), and Cherry Creek (6 percent). The potential for high-density development is increased by the presence of vested lots and plats, particularly in the Patterson and Ames Creeks areas.

Sammamish River Basin

The Sammamish River basin has been urbanizing rapidly since the 1950s. Future development is expected to continue throughout the basin. Bellevue, Kirkland and Redmond have designated potential annexation areas, some of which are within the floodplain.

Cedar River Basin

The greater part of the Cedar River floodplain is in unincorporated King County, with a smaller portion in the City of Renton. There is commercial, industrial and residential development throughout the incorporated areas of the Cedar River floodplain. Residential development has also occurred in

unincorporated King County along the lower floodplain reaches, which is likely due to its proximity to Renton. Renton is expected to annex portions of the land along the Cedar River. There is expected to be a significant amount of growth in Renton by 2022 (King County 2005).

Green River Basin

The Green River basin has been urbanizing since the 1970s. In the 1990s, Black Diamond, Enumclaw and Covington experienced rapid growth. Land development estimates indicate that the largest areas of future development will be in the lower and middle Green River areas.

White River Basin

The majority of the White River basin is in unincorporated King County, with a smaller portion in the cities and the Muckleshoot Indian Tribe Reservation. There is commercial, industrial and residential development throughout the incorporated areas of the White River floodplain. The majority of development is along the White River in the Auburn and Pacific area. This area has significant potential for new residential, commercial and industrial development.

11.7 SCENARIO

Historically, floods have had significant impacts in King County. The County can expect significant flooding every two to five years. The duration and intensity of the storms that cause flooding may increase due to climate change. The floodplains mapped and identified by King County will continue to take the brunt of these floods. County residents prepare themselves for flooding by being informed and by pursuing mitigation. The impacts of flood events should decrease as the county, the Flood Control District and residents continue to promote and implement hazard mitigation and preparedness

11.8 ISSUES

Important issues associated with flood hazards include but are not limited to the following:

- FEMA map updates have been on hold due to federal levee policy concerns. This delay perpetuates reliance on obsolete information for flood insurance purposes. It also creates confusion for the public regarding which maps should be used, as some local governments have completed new studies for regulatory purposes.
- The Revised King County Channel Migration Zone Public Rule became effective on March 31, 2014. The revised rule affects mapping efforts and does not alter land use regulations in these areas. The preparation of channel migration zone maps using updated mapping methods will proceed through 2014 and beyond.
- There are many Zone A areas in the County. These areas lack detailed hydraulic analyses, so base flood elevation and flood depth information is unavailable. Updates in these areas would provide more accurate information for hazard awareness and flood insurance rates.
- Although a significant number of flood studies have been completed, further effort is needed to continue to update the remaining major river reaches and larger tributary streams:
  - **Greenwater River**—This is a major tributary to the White River. Detailed flood mapping is only available from Pierce County’s Digital Flood Insurance Rate Map. But that study is based on regression equations that relate peak discharge-frequency data to drainage area and mean annual precipitation. An updated, detailed flood study is needed to reflect current conditions at a riverside residential community along the lowermost portion of the river.

- **White River Above Mud Mountain Dam**—This segment of the White River has only an approximate flood study, with no flood elevations and no delineated floodway. Significant flood inundation of State Route 410 has occurred, forcing closure of this state roadway. Fast erosive floodwaters have exposed riverside residents to life-threatening conditions and loss of homes. New flood hazard information could be used to educate area residents about potential risks and as a basis for planning effective flood risk reduction solutions.
- **White River Muckleshoot Reach**—This segment of the White River has no flood hazard mapping. While much of the river is within Muckleshoot Indian Tribe jurisdiction, developable areas would benefit from accurate delineation of hazard areas to avoid future at-risk land uses.

- Although King County has completed numerous river flood studies, many studies are based on older data. King County should evaluate whether these studies adequately represent current flood hazards.
- More information on flood risk is needed to support risk-based analysis of capital projects.
- A sustained effort should be made to gather historical damage data, such as high water marks on structures and damages reports. The collection of this information will assist with determining the cost-effectiveness of future mitigation projects and will provide more information on the nature of the hazard.
- Ongoing flood hazard mitigation will require funding from multiple sources to continue.
- Flood hazards do not recognize jurisdictional boundaries, and actions in jurisdictions can impact upstream or downstream neighbors. Coordination is necessary to ensure that these connections are understood and hazards are effectively mitigated.
- Floodplain residents need to continue to be educated about flood preparedness and the resources available during and after floods. Flood preparedness can help residents reduce risk to property and lives. Resources that are made available after flood events can help residents make informed decisions that may mitigate future risk to lives and property.
- The risk associated with the flood hazard overlaps the risk associated with other hazards, such as earthquake and landslide. This provides an opportunity to seek mitigation alternatives that can reduce risk for multiple hazards.
- The location of hazardous materials within the floodplain could result in secondary hazards during or after a flood event. Additional risk analysis should be performed on any such facilities within the County.
- The accuracy of existing FEMA flood hazard mapping for the planning area in reflecting the true flood risk is questionable. FEMA maps do not recognize residual risk outside the mapped area. Where levees are accredited, there may be a misperception that there is no flood risk. Public outreach and awareness efforts should, therefore, emphasize the residual risk behind levees. Additionally, the risk to areas protected by levees not accredited by the FEMA mapping process may not be understood by residents. Furthermore, FEMA map data is often outdated and does not reflect updated flood studies.
- The concept of residual risk should be considered in the design of future capital flood control projects and should be communicated with residents living in the floodplain.
- There is no degree of consistency of land-use practices and regulatory floodplain management scope within the planning area. An external advisory review panel convened by King County to look at conditions along the Green River concluded: “Considering the development that has occurred in the Lower Green River floodplain, it is evident to the review panel that this lack of

regulatory consistency has resulted in a significant increase in risk exposure over time." The panel identified actions that would strive to achieve regulatory consistency for the Green River that could be applied county-wide.

- The impacts of climate change on flood impacts in the planning area are uncertain.
- The promotion of flood insurance as a means of protecting private property owners from the economic impacts of frequent flood events should continue.
- Existing floodplain-compatible uses such as agricultural and open space need to be maintained. There is constant pressure to convert these existing uses to more intense uses within the planning area during times of moderate to high growth.
- Jurisdictions should be adequately resourced to maintain up-to-date hazard information and take appropriate mitigation actions to reduce risk in their community.

CHAPTER 12.

LANDSLIDE

12.1 GENERAL BACKGROUND

A landslide is a mass of rock, earth or debris moving down a slope. Landslides may be minor or very large, and can move at slow to very high speeds. They can be initiated by storms, earthquakes, fires, volcanic eruptions or human modification of the land.

> **DEFINITIONS**
>
> **Landslide—**The sliding movement of masses of loosened rock and soil down a hillside or slope. Such failures occur when the strength of the soils forming the slope is exceeded by the pressure, such as weight or saturation, acting upon them.
>
> **Mass Movement—**A collective term for landslides, debris flows, falls and sinkholes.
>
> **Mudslide (or Mudflow or Debris Flow)—**A river of rock, earth, organic matter and other materials saturated with water.

Mudslides (or mudflows or debris flows) are rivers of rock, earth, organic matter and other soil materials saturated with water. They develop in the soil overlying bedrock on sloping surfaces when water rapidly accumulates in the ground, such as during heavy rainfall or rapid snowmelt. Water pressure in the pore spaces of the material increases to the point that the internal strength of the soil is drastically weakened. The soil's reduced resistance can then easily be overcome by gravity, changing the earth into a flowing river of mud. A mudflow can move rapidly down slopes or through channels and can strike with little or no warning. The material can travel miles from its source, growing as it descends, picking up trees, boulders, cars and anything else in its path. Although these slides behave as fluids, they pack many times the hydraulic force of water due to the mass of material included in them.

Landslides can be some of the most destructive events in nature, posing a serious hazard to properties on or below hillsides. When landslides occur—in response to such changes as increased water content, earthquake shaking, addition of load, or removal of downslope support—they deform and tilt the ground surface. The result can be destruction of foundations, offset of roads, breaking of underground pipes, or overriding of downslope property and structures.

12.1.1 Landslide Types and Run-Out

Two characteristics are essential to conducting an accurate risk assessment of the landslide hazard:

- The type of initial ground failure that occurs
- The post-failure movement of the loosened material ("run-out"), including travel distance and velocity.

Landslides are commonly categorized by the type of initial ground failure. Figure 12 -43 through Figure 12 -46 show common types of slides (Ecology, 2014). The most common is the shallow colluvial slide, occurring particularly in response to intense, short-duration storms. The largest and most destructive are deep-seated slides, although they are less common than other types.

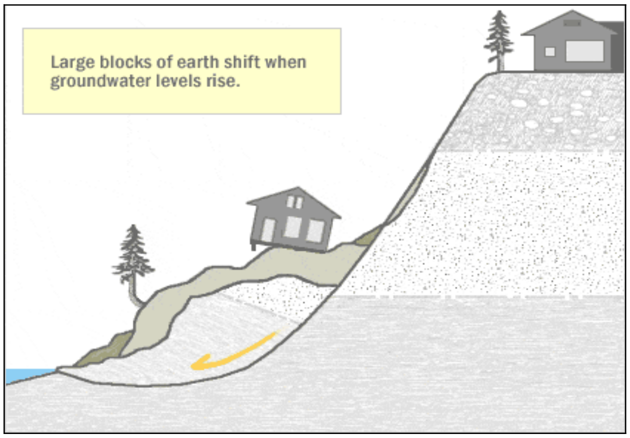


Figure 12-43. Deep Seated Slide

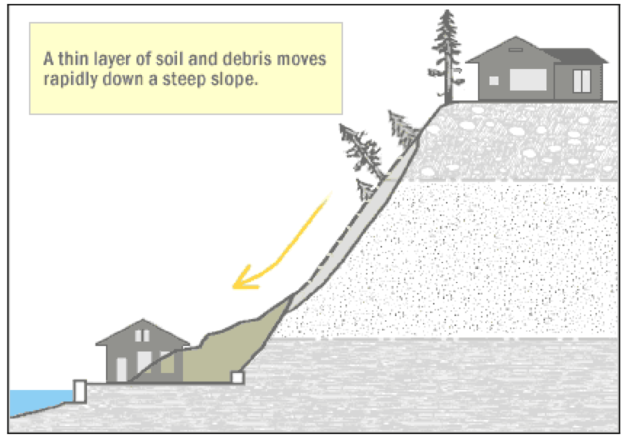


Figure 12-44. Shallow Colluvial Slide

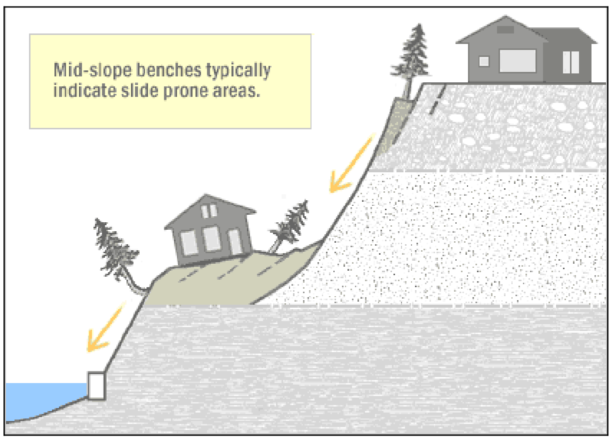


Figure 12-45. Bench Slide

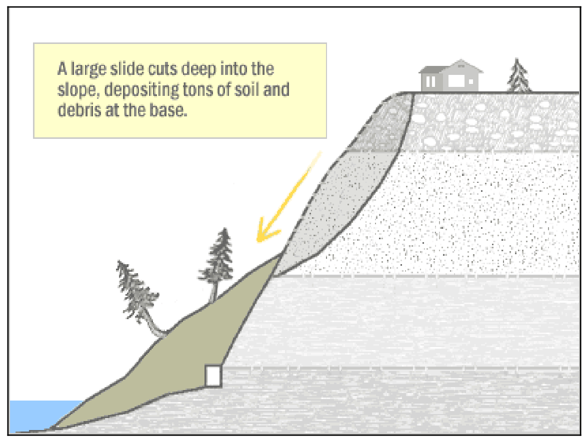


Figure 12-46. Large Slide

All current landslide models—those in practical applications and those more recently developed—use simplified hypothetical descriptions of mass movement to simulate the complex behavior of actual flow. The models attempt to reproduce the general features of the moving mass of material through measurable factors, such as base shear, that define a system and determine its behavior. Due to the lack of experimental data and the limited current knowledge about the behavior of the moving flows, landslide models use simplified parameters to account for complex aspects that may not be defined. These simplified parameters are not related to specific physical processes that can be directly measured, and there is a great deal of uncertainty in their definition. Some, but not all, models provide estimates of the level of uncertainty associated with the modeling approach.

Run-out modeling is complicated because the movement of materials may change over the course of a landslide event, depending on the initial composition, the extent of saturation by water, the ground shape of the path traveled and whether there is additional material incorporated during the event (Savage and Hutter 1991; Rickenmann 2000; Iverson et al. 2004).

12.1.2 Landslide Causes

Mass movements are caused by a combination of geological and climate conditions, as well as the encroaching influence of urbanization. Vulnerable natural conditions are affected by human residential, agricultural, commercial and industrial development and the infrastructure that supports it. The following factors can contribute to landslide: change in slope of the terrain, increased load on the land, shocks and

vibrations, change in water content, groundwater movement, frost action, weathering of rocks, and removing or changing the type of vegetation covering slopes.

Excavation and Grading

Slope excavation is common in the development of home sites or roads on sloping terrain. Grading can result in some slopes that are steeper than the pre-existing natural slopes. Since slope steepness is a major factor in landslides, these steeper slopes can be at an increased risk for landslides. The added weight of fill placed on slopes can also result in an increased landslide hazard. Small landslides can be fairly common along roads, in either the road cut or the road fill. Landslides occurring below new construction sites are indicators of the potential impacts stemming from excavation.

A study conducted by Burns and others at Portland State University found that changes to the slope through cutting or filling increased the risk of 76 percent of inventoried landslides in the Portland Metro region. The study documented 48 landslides that occurred in Oregon City in February 1996, and found that only about half the slides were considered natural.

Drainage and Groundwater Alterations

Water flowing through or above ground is often the trigger for landslides. Any activity that increases the amount of water flowing into landslide-prone slopes can increase landslide hazards. Broken or leaking water or sewer lines can be especially problematic, as can water retention facilities that direct water onto slopes. However, even lawn irrigation and minor alterations to small streams in landslide prone locations can result in damaging landslides. Ineffective stormwater management and excess runoff can also cause erosion and increase the risk of landslide hazards. Drainage can be affected naturally by the geology and topography of an area. Development that results in an increase in impervious surface impairs the ability of the land to absorb water and may redirect water to other areas. Channels, streams, flooding, and erosion on slopes all indicate potential slope problems.

Road and driveway drains, gutters, downspouts, and other constructed drainage facilities can concentrate and accelerate flow. Ground saturation and concentrated velocity flow are major causes of slope problems and may trigger landslides.

Changes in Vegetation

Removing vegetation from very steep slopes can increase landslide hazards. A study by the Oregon Department of Forestry found that landslide hazards in three out of four steeply sloped areas were highest for a period of roughly 10 years after timber harvesting (Oregon Department of Forestry, 1999). Areas that have experienced wildfire and land clearing for development may have long periods of increased landslide hazard. In addition, woody debris in stream channels (both natural and man-made from logging) may cause the impacts from debris flows to be more severe.

12.1.3 Landslide Management

Landslides are common features in river and stream valleys across King County. While small landslides are often a result of human activity, the largest landslides are often naturally occurring phenomena with little or no human contribution. The sites of large landslides are typically areas of previous landslide movement that are periodically reactivated by significant precipitation or seismic events. Such naturally occurring landslides can disrupt roadways and other infrastructure lifelines, destroy private property, and cause flooding, bank erosion and rapid channel migration.

Landslides can create immediate, critical threats to public safety. Engineering solutions to protect structures on or adjacent to large active landslides are often extremely or prohibitively expensive. In spite

of their destructive potential, landslides are a part of the natural landscape of King County river valleys. They supply sediment and large wood to the channel network and can contribute to complexity and dynamic channel behavior critical for aquatic and riparian ecological diversity. Effective landslide management should include the following elements:

- Continuing investigation to identify natural landslides, understand their mechanics, assess their risk to public health and welfare, and understand their role in ecological systems
- Regulation of development in or near existing landslides or areas of natural instability through the King County Critical Areas Ordinance in King County Code Chapter 21A.24, the clearing and grading standards in King County Code Chapter 16.82, and the King County Surface Water Design Manual
- Preparation for emergency response to landslides to facilitate rapid, coordinated action among King County, local cities, and state and federal agencies, and to provide emergency assistance to affected or at-risk citizens
- Evaluation of options including landslide stabilization or structure relocation where landslides are identified that threaten critical public structures or infrastructure, such as the Auburn-Black Diamond Road project and the Sinnema Quaale Upper Project.

Because landslides regularly disrupt freight and commuter rail services that follow the Puget Sound shoreline, the Washington State Department of Transportation and BNSF Railway are involved in a federally funded project to increase the reliability of the rail corridor service between Vancouver, Washington and the Canadian border. Actions being taken to reduce impacts include geotechnical investigations, historical slide research, investigation of potential slide area investigations, construction of retaining walls, improvements to drainage systems, and implementation of erosion control strategies (Washington State Department of Transportation, 2014a). Washington State also has provided funding for preventive drainage maintenance and debris removal activities between Seattle and Shoreline (Washington State Department of Transportation, 2014b).

12.2 HAZARD PROFILE

12.2.1 Past Events

The majority of significant slide events in King County have occurred during or shortly after storm events. The following are significant slide events that have occurred in the county (King County, 2009; Washington Emergency Management Division, 2010; Seattle Office of Emergency Management, 2014):

- 900 AD—After a Seattle Fault event, landslides were triggered on Mercer Island and Lake Sammamish (Washington Emergency Management Division, 2010).
- 1949—Multiple landslides occurred in the Puget Sound region after a Magnitude-7.1 earthquake event. Urban slides occurred in areas of fill and areas made unstable by undercutting (Washington Emergency Management Division, 2010).
- 1965—At least 21 landslides were triggered from ground shaking within 60 miles of the epicenter of the Seattle-Tacoma earthquake event, including events in West and South Seattle, Auburn, near Maple Valley and at Mount Si near North Bend (Washington Emergency Management, 2010).
- 1972—King County experienced $1.8 million in public damage as a result of slide events.
- 1983—A slide in the Queen Anne neighborhood of Seattle closed Aurora Avenue.
- 1994—Five homes were destroyed in the Magnolia neighborhood of Seattle as the result of a slump.

- 1996—More than 40 slides were recorded in Seattle over the duration of the 1995/1996 winter, two-thirds of which were a result of a February storm. A slide also occurred east of Enumclaw, blocking State Route 410.
- 1996-1997—King County experienced $9.0 million in combined public damage after hundreds of landslides were triggered, predominantly along the shorelines of Puget Sound, Lake Washington, Lake Union and Portage Bay, and in West Seattle, Magnolia Bluff and the I-5 corridor. There were more than 130 recorded slides on the shorelines between Seattle and Everett, including one that derailed five cars of a freight train.
- 2001—Slides on the Cedar River triggered by the Nisqually Earthquake caused $1.71 million in public damage. Five homes in Burien were damaged. Damage was also reported at the King County International Airport/Boeing Field, Harbor Island, State Route 202 near Snoqualmie and Interstate 405 in Renton.
- 2004—Two slide events in January disrupted transportation routes: a North Seattle slide disrupted Sounder commuter train service; and a slide closed the I-90 on-ramp in Issaquah. In March, a landslide near Renton partially dammed the Cedar River.
- 2005—In May, 11 homes were isolated after a small slide on Mercer Island. In September, two lanes of I-90 west of Snoqualmie Pass were closed after a rockslide. In December, Juanita Drive in northeast Kirkland was closed after a slide.
- 2006—In January, landslides closed numerous lanes of Interstate 5. Four slides were triggered between Seattle and Everett. At least two slides occurred on Mercer Island and one occurred in Seattle’s University District. A slide closed Issaquah Hobart Road near Tiger Mountain. A slide partially buried a house east of Renton. Three slides occurred near Maple Valley and the Cedar River. A slide closed Lake Dorothy Road in North Bend. Multiple slides closed commuter rail service, including one in Shoreline. In March, a slide isolated five homes on Mercer Island. Slides across King County in November included one that isolated 200 homes after access was blocked to Upper Preston Road. In mid-December, there were five landslides in Seattle and another slide that covered railroad tracks.
- 2007—Five slides were recorded in King County.
- 2008—In July, a slide occurred in Bellevue at a construction site for a subdivision after a thunderstorm. In November, State Road 410 was closed as the result of a debris flow east of Enumclaw. A landslide caused damage to the Green River Bridge on State Route 169 that resulted in the bridge being closed for repairs for eight months.
- 2009—There were 51 recorded slides. Numerous slides occurred in the Cascade foothills in January. This storm also created the potential for the reactivation of movement underneath Howard Hansen Dam.
- 2014—The multiple-fatality Oso landslide in Snohomish County occurred as this hazard mitigation plan was being prepared. The number of fatalities and damage costs had not been finalized by the time of this plan’s completion.

Over the past decade, more than 200 landslides occurred along the Seattle to Everett coastline, and more than 800 trains have been canceled since 2009 as a result of landslide events (Washington State Department of Transportation, 2014). Between December 2012 and January 2013, coastline rail service disruption due to landslide events occurred at record levels.

12.2.2 Location

Slides occur in urban and rural areas throughout the County. The shorelines of Puget Sound are particularly vulnerable to slide events. In general, landslide hazard areas are where the land has characteristics that contribute to the risk of the downhill movement of material, such as the following:

- A slope greater than 33 percent
- A history of landslide activity or movement during the last 10,000 years
- Stream or wave activity, which has caused erosion, undercut a bank or cut into a bank to cause the surrounding land to be unstable
- The presence or potential for snow avalanches
- The presence of an alluvial fan, indicating vulnerability to the flow of debris or sediments
- The presence of impermeable soils, such as silt or clay, which are mixed with granular soils such as sand and gravel.

The best available predictor of where movement of slides and earth flows might occur is the location of past movements. Past landslides can be recognized by their distinctive topographic shapes, which can remain in place for thousands of years. Most landslides recognizable in this fashion range from a few acres to several square miles. Most show no evidence of recent movement and are not currently active. A small proportion of them may become active in any given year, with movements concentrated within all or part of the landslide masses or around their edges. Ancient dormant mass movement sites can be reactivated by earthquakes or by exceptionally wet weather. Also, because they consist of broken materials and frequently involve disruption of groundwater flow, these dormant sites are vulnerable to construction-triggered sliding. A landslide study for the City of Seattle analyzed more than 1,300 slides that had occurred in the City since 1890 and found that only 58 percent occurred in what were then known to be potential slide areas. Potential slide areas were remapped using the historical record of slide activity as the primary factor (Shannon & Wilson, 2000).

Landslides also occur in areas where no previous slides have been recorded. According to the Washington State Hazard Mitigation Plan, the geology of the Puget Sound lowlands predisposes much of the terrain to slide events, especially along steep coastal bluffs. The last continental glaciation deposited unconsolidated glacial till on top of impermeable bedrock. Channels eroded by glacial melt water and further eroded by precipitation and wave action have left over-steepened and unsupported slopes (Washington Emergency Management Division, 2010). Under the right conditions, these slopes are prone to landslides.

The Seattle landslide study found that human influence played some role in 84 percent of recorded slides. Critical area ordinances at the local level reduce the impacts of human alterations on critical areas, which include geologically hazardous areas such as areas prone to landslide, erosion, mass-wasting, debris flows and rock falls. The designation of critical areas, including geologically hazardous areas, is a requirement of the Washington State Growth Management Act (WAC 365-190-080(4). The King County zoning code generally discourages development in landslide hazard areas, but it allows development in certain instances where avoidance is not desirable or practical. The King County Critical Areas Ordinance establishes differential regulations for landslide hazard areas on slopes greater than 40 percent (King County DPER, 2014). According to the King County Critical Areas Ordinance Manual, “In general, all alterations are allowed on landslide hazard areas provided that the landslide hazard itself is mitigated through proper engineering of the development so that the risk of property damage and injury is minimized or eliminated.” Each incorporated area in the County has established its own rules and regulations pertaining to development in critical areas.

Landslide hazard areas and steep slopes within the planning area are shown on Figure 12 -47. The map represents landslide location data from the Washington Department of Natural Resources, a landslide hazard data set from King County, and a data set created using surface geology and digital elevation model data provided by King County, as follows:

- Digital elevation model data defining slopes was taken from a LiDAR-derived bare-earth elevation raster collected in 2002.
- Surface geology data was taken from Pacific Northwest Center for Geologic Mapping Studies, 2006.
- Potential landslide hazard areas were defined as all areas with a slope greater than 40 percent (from the LiDAR data) and one of the following soil types (from the surface geology data):
  - Q_{ls} soils, indicating areas of discrete landslide
  - Q_{mw} soils, indicating areas of colluvium and the cumulative debris from small indistinct landslides that accumulate on and at the base of unstable slopes
  - Q_f soils, indicating alluvial fans, which are formed by the deposition of sediment from floods and debris flows at a point where a steep drainage course discharges onto an area of low gradient.

12.2.3 Frequency

Several landslides occur in King County every year. According to records from the Spatial Hazard Events and Losses Database for the United States (SHELDUS), the planning area has been impacted by severe storms at least once every other year since 1960. Until better countywide data is generated for the landslide hazard, this frequency is appropriate for ranking the risk associated with the landslide hazard. Landslides are often triggered by other natural hazards such as earthquakes, heavy rain, floods or wildfires, so landslide frequency is often related to the frequency of these other hazards.

Slides can occur at any time, although most occur during the rainy season. Most local landslides occur in January after the water table has risen during the wet months of November and December. In King County, landslides typically occur during and after major storms, so the potential for landslides largely coincides with the potential for sequential severe storms that saturate steep, vulnerable soils. Precipitation influences the timing of landslides on three scales: total annual rainfall, monthly rainfall, and single precipitation events. In general, landslides are most likely during periods of higher than average rainfall.

The ground must be saturated prior to the onset of a major storm for significant landsliding to occur. Studies conducted by the USGS have identified two precipitation thresholds to help identify when landslides are likely (USGS, 2007):

- Cumulative Precipitation Threshold (Figure 12 -48)—A measure of precipitation over the last 18 days, indicating when the ground is wet enough to be susceptible to landslides. Rainfall of 3.5 to 5.3 inches is required to exceed this threshold, depending on how much rain falls in the last 3 days.
- Intensity Duration Threshold (Figure 12 -49)—A measure of rainfall during a storm, indicating when it is raining hard enough to cause multiple landslides if the ground is already wet.

These thresholds are most likely to be crossed during the rainy season, so slide events in the planning area most commonly occur from January through March.

Insert Landslide Hazard Areas Map

Figure 12-47. Landslide Hazard Areas.

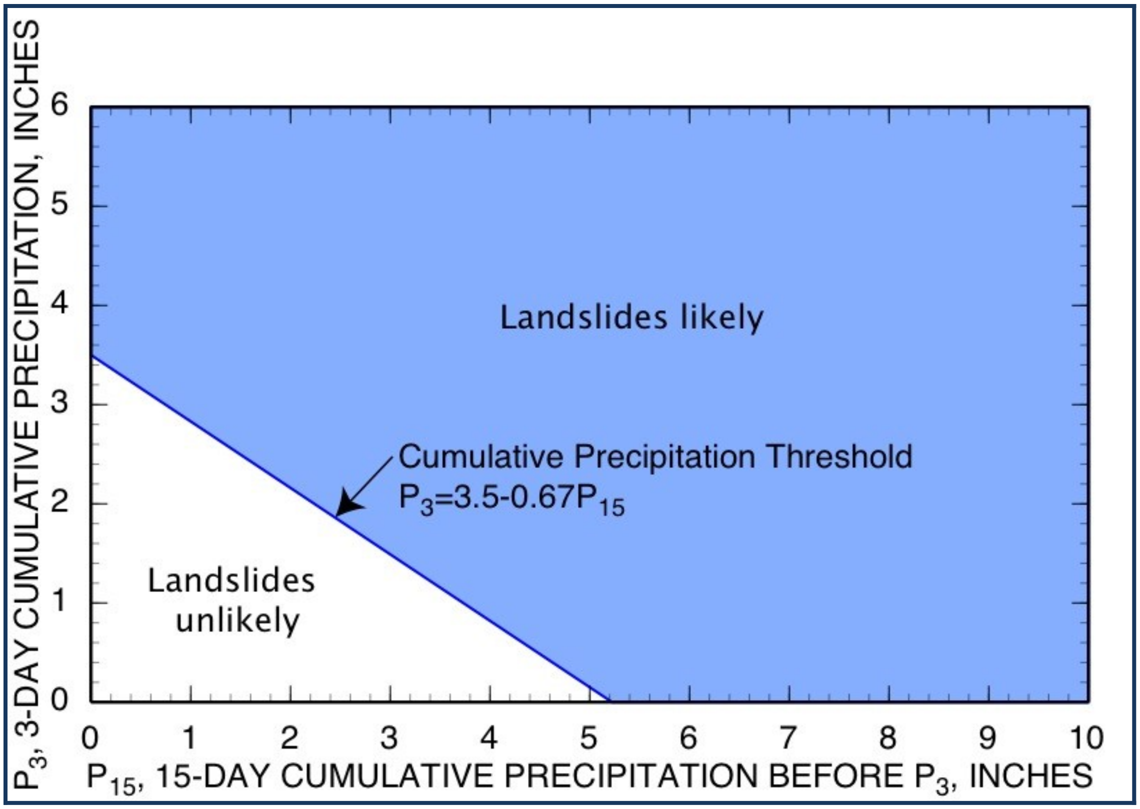


Figure 12-48. Cumulative Precipitation Threshold

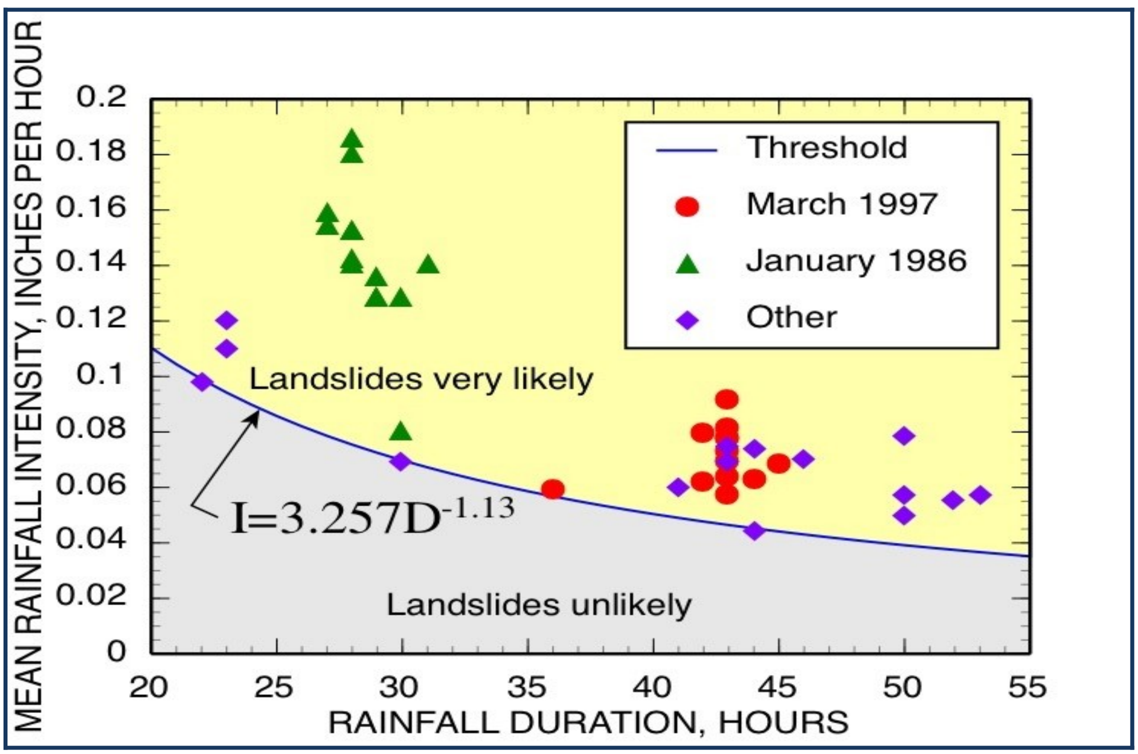


Figure 12-49. Intensity Duration Threshold

12.2.4 Severity

Landslides destroy property and infrastructure and can take the lives of people. Slope failures in the United States result in an average of 25 lives lost per year and an annual cost to society of about $1.5 billion. The recent event in Oso, Washington showed the devastating potential that can be caused by landslides. The costs in lives and property damage have not been finalized as of the time that this hazard mitigation plan is being prepared, but this event may be the deadliest landslide event in Washington State history. Its proximity to King County has heightened the awareness of the severity of this hazard in the planning area.

Thousands of landslides have occurred within King County, but there is no consolidated database of them. Landslide events often occur concurrently with other hazard events, so damage estimates specifically related to landslide are difficult to obtain. SHELDUS lists 10 landslide events in the planning area since 1965. The combined estimated damage for these events exceeded $3.3 million. There have been hundreds of slide events in the County over the last several decades, so it is likely that the true costs of landslide damage in the County has been far greater. There are no records of fatalities attributed to mass movement in the County. However, deaths have occurred in neighboring Washington counties and across the west coast as a result of slides and slope collapses.

12.2.5 Warning Time

Mass movements can occur suddenly or slowly. The velocity of movement may range from a slow creep of inches per year to many feet per second, depending on slope angle, material and water content. Generally accepted warning signs for landslide activity include the following:

- Springs, seeps, or saturated ground in areas that have not typically been wet before
- New cracks or unusual bulges in the ground, street pavements or sidewalks
- Soil moving away from foundations
- Ancillary structures such as decks and patios tilting and/or moving relative to the main house
- Tilting or cracking of concrete floors and foundations
- Broken water lines and other underground utilities
- Leaning telephone poles, trees, retaining walls or fences
- Offset fence lines
- Sunken or down-dropped road beds
- Rapid increase in creek water levels, possibly accompanied by increased turbidity (soil content)
- Sudden decrease in creek water levels though rain is still falling or just recently stopped
- Sticking doors and windows, and visible open spaces indicating frames out of plumb
- A faint rumbling sound that increases in volume as the landslide nears
- Unusual sounds, such as trees cracking or boulders knocking together.

Some methods used to monitor mass movements can provide an idea of the type of movement and the amount of time prior to failure. Assessing the geology, vegetation and amount of predicted precipitation for an area can help in predictions of what areas are at risk during general time periods. Currently, there is no practical warning system for individual landslides. The standard operating procedure is to monitor situations on a case-by-case basis and respond after an event has occurred.

The Washington Division of Geology and Earth Resources, in cooperation with NOAA, has developed a landslide warning system that is currently in beta testing. The forecasting model is based on storm and landslide data. It is unlikely that this model will be able to forecast individual landslide events before they occur, but it will be a useful system for alerting residents to be more vigilant about landslide risk.

12.3 SECONDARY HAZARDS

Landslides can cause several types of secondary effects, such as blocking access to roads, which can isolate residents and businesses and delay commercial, public and private transportation. This could result in economic losses for businesses. Other potential problems resulting from landslides are power and communication failures. Vegetation or poles on slopes can be knocked over, resulting in possible losses to power and communication lines. Landslides also have the potential of destabilizing the foundation of structures, which may result in monetary loss for residents. They also can damage rivers or streams, potentially harming water quality, fisheries and spawning habitat.

12.4 EXPOSURE

12.4.1 Population

Population could not be examined by landslide hazard area because census block group areas do not coincide with the hazard areas. A population estimate was made using the structure count of buildings within the landslide hazard areas and applying the census value of 2.39 persons per household for King County. Using this approach, the estimated population living in the landslide risk area is 35,000 or 2.8 percent of the total planning area population.

12.4.2 Property

Table 12 -64 shows the number and assessed value of structures exposed to the landslide risk. There are approximately 24,000 structures on parcels in the landslide risk areas, with an estimated value of $10.1 billion. This represents approximately 1.82 percent of the total assessed value for the planning area. Over 90 percent of the exposed structures are dwellings. Table 12 -65 shows the general land use of parcels exposed to landslides in King County. The vast majority of the land area of parcels (86.5 percent) intersecting landslide hazard areas are uncategorized, which includes vacant and resource lands. Residential parcels make up 8.4 percent of the total acreage.

12.4.3 Critical Facilities and Infrastructure

Table 12 -66 and Table 12 -67 summarize the critical facilities exposed to the landslide hazard. No loss estimates were developed due to the lack of established damage functions for the landslide hazard. A significant amount of infrastructure can be exposed to mass movements:

- **Roads**—Access to major roads is crucial to life-safety after a disaster event and to response and recovery operations. Landslides can block egress and ingress on roads, causing isolation for neighborhoods, traffic problems and delays for public and private transportation. This can result in economic losses for businesses.
- **Bridges**—Landslides can block or damage road bridges. They can knock out bridge abutments or significantly weaken the soil supporting them, making them hazardous for use.
- **Power Lines**—Power lines are generally elevated above steep slopes, but the towers supporting them affected by landslides. A landslide can trigger failure of the soil underneath a tower, causing it to collapse and ripping down the lines. Power and communication failures due to landslides can create problems for vulnerable populations and businesses.

TABLE 12-64.
EXPOSURE AND VALUE OF STRUCTURES IN LANDSLIDE RISK AREAS

	Buildings Exposed	Value Exposed			% of Total Assessed Value
		Structure	Contents	**Total**	
Algona	14.0	$7,522,861	$6,957,820	$14,480,680	1.60%
Auburn	132.0	$115,123,083	$61,450,630	$176,573,713	0.98%
Beaux Arts Village	0.0	$0	$0	$0	0.00%
Bellevue	1748.0	$1,151,250,598	$829,911,013	$1,981,161,610	4.03%
Black Diamond	0.0	$0	$0	$0	0.00%
Bothell	225.0	$135,200,750	$68,341,843	$203,542,593	3.90%
Burien	735.0	$206,988,490	$104,654,051	$311,642,541	3.40%
Carnation	0.0	$0	$0	$0	0.00%
Clyde Hill	0.0	$0	$0	$0	0.00%
Covington	0.0	$0	$0	$0	0.00%
Des Moines	468.0	$163,908,888	$87,218,482	$251,127,370	4.37%
Duvall	0.0	$0	$0	$0	0.00%
Enumclaw	0.0	$0	$0	$0	0.00%
Federal Way	478.0	$152,956,101	$76,736,012	$229,692,113	1.20%
Hunts Point	0.0	$0	$0	$0	0.00%
Issaquah	505.0	$652,601,463	$337,219,604	$989,821,067	10.32%
Kenmore	473.0	$122,363,761	$65,289,738	$187,653,499	4.69%
Kent	122.0	$56,656,876	$28,328,438	$84,985,314	0.26%
Kirkland	899.0	$312,493,103	$159,494,731	$471,987,834	2.13%
Lake Forest Park	756.0	$211,960,182	$108,041,231	$320,001,413	14.45%
Maple Valley	0.0	$0	$0	$0	0.00%
Medina	0.0	$0	$0	$0	0.00%
Mercer Island	0.0	$0	$0	$0	0.00%
Milton	6.0	$978,634	$489,317	$1,467,951	1.04%
Newcastle	122.0	$50,608,456	$25,304,228	$75,912,685	3.35%
Normandy Park	13.0	$3,280,477	$1,640,239	$4,920,716	0.38%
North Bend	30.0	$7,564,531	$3,782,266	$11,346,797	0.78%
Pacific	1.0	$274,382	$137,191	$411,572	0.05%
Redmond	544.0	$199,914,136	$113,443,620	$313,357,757	1.35%
Renton	193.0	$190,774,870	$110,754,702	$301,529,572	1.17%
Sammamish	561.0	$215,893,243	$107,946,621	$323,839,864	3.48%
SeaTac	21.0	$3,829,801	$1,914,900	$5,744,701	0.08%
Seattle	2008.0	$1,112,503,753	$743,694,102	$1,856,197,855	0.87%
Shoreline	548.0	$191,365,011	$96,360,779	$287,725,789	2.58%
Skykomish	0.0	$0	$0	$0	0.00%
Snoqualmie	54.0	$20,169,969	$11,020,692	$31,190,661	1.36%
Tukwila	7.0	$83,309,675	$85,070,953	$168,380,628	1.45%
Woodinville	130.0	$101,006,592	$73,710,254	$174,716,846	3.86%
Yarrow Point	0.0	$0	$0	$0	0.00%
Unincorporated	3,711	$866,952,616	$460,938,164	$1,347,890,780	3.02
Total	0	0	0	0	**1.82%**

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.3.5 for a discussion of data limitations.

**TABLE 12-65.
PRESENT LAND USE IN LANDSLIDE RISK AREAS**

Present Use Category	Area in Landslide Risk Area (acres)	% of total
Agriculture	257	0.1%
Church, Welfare or Religious Service	293	0.1%
Commercial	2,310	0.5%
Education	546	0.1%
Governmental Services	1,355	0.3%
Industrial/Manufacturing	2,085	0.5%
Medical/Dental Services	5	0.0%
Mixed Use Development (Residential & Commercial)	4	0.0%
Mortuary/Cemetery/Crematory	149	0.0%
Nursing Home/Retirement Facility	90	0.0%
Park/Open Space/Golf Course	12,009	2.8%
Residential	36,382	8.4%
Terminal or Marina	178	0.0%
Water/Tideland/Wetland	6	0.0%
Uncategorized (includes vacant and resource lands)	375,153	86.5%
Utility/Easement/Right of Way	3,128	0.0%
Total	**433,951**	**100%**

Source: Summarized from King, Pierce and Snohomish County parcel data. Acreage covers only mapped parcel extents and thus excludes many rights of way and major water features. Acreage consists only of those areas intersecting mapped hazard layers.

TABLE 12-66.
CRITICAL FACILITIES IN LANDSLIDE RISK AREAS

	Medical and Health	Government Functions	Protective Functions	Schools	Hazmat	Other Critical Functions	**Total**
Algona	0	0	0	0	0	1	**1**
Auburn	0	0	0	0	0	0	**0**
Beaux Arts Village	0	0	0	0	0	0	**0**
Bellevue	0	0	1	1	0	1	**3**
Black Diamond	0	0	0	0	0	0	**0**
Bothell	0	0	0	0	0	0	**0**
Burien	1	0	0	0	0	0	**1**
Carnation	0	0	0	0	0	0	**0**
Clyde Hill	0	0	0	0	0	0	**0**
Covington	0	0	0	0	0	0	**0**
Des Moines	0	0	0	0	0	0	**0**
Duvall	0	0	0	0	0	0	**0**
Enumclaw	0	0	0	0	0	0	**0**
Federal Way	0	0	0	0	0	0	**0**
Hunts Point	0	0	0	0	0	0	**0**
Issaquah	0	0	0	0	0	0	**0**
Kenmore	0	0	0	0	0	0	**0**
Kent	0	0	0	0	0	0	**0**
Kirkland	0	0	0	0	0	0	**0**
Lake Forest Park	0	0	0	0	0	0	**0**
Maple Valley	0	0	0	0	0	0	**0**
Medina	0	0	0	0	0	0	**0**
Mercer Island	0	0	0	0	0	0	**0**
Milton	0	0	0	0	0	0	**0**
Newcastle	0	0	0	0	0	0	**0**
Normandy Park	0	0	0	0	0	0	**0**
North Bend	0	0	0	0	0	0	**0**
Pacific	0	0	0	0	0	0	**0**
Redmond	0	0	0	0	0	3	**3**
Renton	0	0	0	1	0	0	**1**
Sammamish	0	0	0	1	0	0	**1**
SeaTac	0	0	0	0	0	0	**0**
Seattle	3	0	2	0	1	2	**8**
Shoreline	0	0	0	0	0	0	**0**
Skykomish	0	0	0	0	0	0	**0**
Snoqualmie	0	0	0	0	0	0	**0**
Tukwila	0	0	0	0	0	0	**0**
Woodinville	0	0	0	0	0	0	**0**
Yarrow Point	0	0	0	0	0	0	**0**
Unincorporated	1	0	1	1	0	0	**3**
Total	**5**	**0**	**4**	**4**	**1**	**7**	**21**

TABLE 12-67.
CRITICAL INFRASTRUCTURE IN LANDSLIDE RISK AREAS

	Bridges	Transportation	Water Supply	Wastewater	Power	Communications	Dams	**Total**
Algona	0	0	0	0	0	0	0	**0**
Auburn	1	0	2	0	0	0	0	**3**
Beaux Arts Village	0	0	0	0	0	0	0	**0**
Bellevue	0	0	0	0	0	0	0	**0**
Black Diamond	0	0	0	0	0	0	0	**0**
Bothell	0	0	3	0	0	0	0	**3**
Burien	0	0	2	2	0	0	0	**4**
Carnation	0	0	0	0	0	0	0	**0**
Clyde Hill	0	0	0	0	0	0	0	**0**
Covington	0	0	0	0	0	0	0	**0**
Des Moines	4	0	1	21	0	0	0	**26**
Duvall	0	0	0	0	0	0	0	**0**
Enumclaw	0	0	0	0	0	0	0	**0**
Federal Way	1	0	0	0	0	0	1	**2**
Hunts Point	0	0	0	0	0	0	0	**0**
Issaquah	3	0	9	1	0	0	0	**13**
Kenmore	5	0	0	0	0	0	0	**5**
Kent	0	0	0	0	0	0	1	**1**
Kirkland	0	0	0	0	0	0	0	**0**
Lake Forest Park	0	0	0	0	0	0	0	**0**
Maple Valley	0	0	0	0	0	0	0	**0**
Medina	0	0	0	0	0	0	0	**0**
Mercer Island	0	0	0	0	0	0	0	**0**
Milton	0	0	0	0	0	0	0	**0**
Newcastle	1	0	0	0	0	0	0	**1**
Normandy Park	0	0	0	0	0	0	0	**0**
North Bend	0	0	2	0	0	0	0	**2**
Pacific	0	0	0	0	0	0	0	**0**
Redmond	0	0	0	1	0	0	0	**1**
Renton	0	0	0	1	0	0	0	**1**
Sammamish	1	0	0	0	0	0	0	**1**
SeaTac	1	0	0	0	0	0	0	**1**
Seattle	1	1	0	2	0	0	0	**4**
Shoreline	1	0	0	5	0	0	1	**7**
Skykomish	0	0	0	0	0	0	0	**0**
Snoqualmie	0	0	0	3	0	0	1	**4**
Tukwila	3	0	0	0	0	0	0	**3**
Woodinville	0	0	1	0	0	0	0	**1**
Yarrow Point	0	0	0	0	0	0	0	**0**
Unincorporated	32	2	5	1	0	0	3	**43**
Total	0	0	0	0	0	0	0	0

12.4.4 Environment

Landslides that fall into streams may significantly impact fish and wildlife habitat, as well as affecting water quality. Hillsides that provide wildlife habitat can be lost for prolonged periods of time due to landslides. However, landslides also provide integral resources for many ecosystems. They contribute needed sediment and wood for building complex in-stream habitats, estuarine marshes, and beaches that are important for fisheries, wildlife and recreation (Washington Department of Community, Trade and Economic Development, 2007).

12.5 VULNERABILITY

12.5.1 Population

Due to the nature of census block group data, it is difficult to estimate populations vulnerable to landslides. In general, all of the estimated 35,000 persons exposed to the landslide hazard are considered to be vulnerable. Increasing population, and the fact that many homes are built on view property atop or below bluffs and on steep slopes subject to mass movement, increases the number of lives endangered by this hazard.

12.5.2 Property

Although complete historical documentation of the landslide threat in the planning area is lacking, the landslides of 1997 and 2006 suggest a significant vulnerability to such hazards. The millions of dollars in damage countywide attributable to mass movement during those storms affected private property and public infrastructure and facilities.

Loss estimations for the landslide hazard are not based on modeling using damage functions, because no such damage functions have been generated. Instead, loss potential was developed representing 10 percent, 30 percent and 50 percent of the assessed value of exposed structures. This allows emergency managers to select a range of economic impact based on an estimate of the percent of damage to the general building stock. Damage in excess of 50 percent is considered to be substantial by most building codes and typically requires total reconstruction of the structure. Table 12 -68 shows the general building stock loss estimates in landslide risk areas.

12.5.3 Critical Facilities and Infrastructure

There are 147 critical facilities and infrastructure exposed to the landslide hazard to some degree. A more in-depth analysis of the mitigation measures taken by these facilities to prevent damage from mass movements should be done to determine if they could withstand impacts of a mass movement.

Infrastructure exposed to landslides includes transportation, water and sewer and power infrastructure. Highly susceptible areas of the county include mountain and coastal roads and transportation infrastructure. At this time all infrastructure and transportation corridors identified as exposed to the landslide hazard are considered vulnerable until more information becomes available.

12.5.4 Environment

The environment vulnerable to landslide hazard is the same as the environment exposed to the hazard.

TABLE 12-68.
LOSS POTENTIAL FOR LANDSLIDE

		Estimated Loss Potential from Landslide		
	Exposed Value	10% Damage	30% Damage	50% Damage
Algona	$14,480,680	$1,448,068	$4,344,204	$7,240,340
Auburn	$176,573,713	$17,657,371	$52,972,114	$88,286,856
Beaux Arts Village	$0	$0	$0	$0
Bellevue	$1,981,161,610	$198,116,161	$594,348,483	$990,580,805
Black Diamond	$0	$0	$0	$0
Bothell	$203,542,593	$20,354,259	$61,062,778	$101,771,297
Burien	$311,642,541	$31,164,254	$93,492,762	$155,821,270
Carnation	$0	$0	$0	$0
Clyde Hill	$0	$0	$0	$0
Covington	$0	$0	$0	$0
Des Moines	$251,127,370	$25,112,737	$75,338,211	$125,563,685
Duvall	$0	$0	$0	$0
Enumclaw	$0	$0	$0	$0
Federal Way	$229,692,113	$22,969,211	$68,907,634	$114,846,057
Hunts Point	$0	$0	$0	$0
Issaquah	$989,821,067	$98,982,107	$296,946,320	$494,910,533
Kenmore	$187,653,499	$18,765,350	$56,296,050	$93,826,749
Kent	$84,985,314	$8,498,531	$25,495,594	$42,492,657
Kirkland	$471,987,834	$47,198,783	$141,596,350	$235,993,917
Lake Forest Park	$320,001,413	$32,000,141	$96,000,424	$160,000,707
Maple Valley	$0	$0	$0	$0
Medina	$0	$0	$0	$0
Mercer Island	$0	$0	$0	$0
Milton	$1,467,951	$146,795	$440,385	$733,975
Newcastle	$75,912,685	$7,591,268	$22,773,805	$37,956,342
Normandy Park	$4,920,716	$492,072	$1,476,215	$2,460,358
North Bend	$11,346,797	$1,134,680	$3,404,039	$5,673,398
Pacific	$411,572	$41,157	$123,472	$205,786
Redmond	$313,357,757	$31,335,776	$94,007,327	$156,678,878
Renton	$301,529,572	$30,152,957	$90,458,872	$150,764,786
Sammamish	$323,839,864	$32,383,986	$97,151,959	$161,919,932
SeaTac	$5,744,701	$574,470	$1,723,410	$2,872,351
Seattle	$1,856,197,855	$185,619,785	$556,859,356	$928,098,927
Shoreline	$287,725,789	$28,772,579	$86,317,737	$143,862,895
Skykomish	$0	$0	$0	$0
Snoqualmie	$31,190,661	$3,119,066	$9,357,198	$15,595,330
Tukwila	$168,380,628	$16,838,063	$50,514,188	$84,190,314
Woodinville	$174,716,846	$17,471,685	$52,415,054	$87,358,423
Yarrow Point	$0	$0	$0	$0
Unincorporated	1,347,890,780	$134,789,078	$404,367,204	$673,945,390
Total	0	0	0	0

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.3.5 for a discussion of data limitations.

12.6 FUTURE TRENDS IN DEVELOPMENT

The County and its planning partners are equipped to handle future growth in landslide hazard areas. All municipal planning partners have comprehensive plans that define landslide hazard areas as critical areas. All partners have committed to linking their comprehensive plans to this hazard mitigation plan update. This will facilitate wise land use decisions as future growth impacts landslide hazard areas.

The State of Washington has adopted the International Building Code (IBC) by reference in its Washington Building Standards Code. The IBC includes provisions for geotechnical analyses in steep slope areas that have soil types considered susceptible to landslide hazards. These provisions ensure that new construction is built to standards that reduce vulnerability to the landslide risk.

12.7 SCENARIO

The worst-case scenario for landslide in the planning area would be a severe storm with heavy rain that pushes precipitation levels above the thresholds identified by USGS, followed by an earthquake. This scenario is most likely to occur during late winter when the water table is high. A recent study by Kate Allstadt and others and published online by the Bulletin of the Seismological Society of America assessed the effects of landslides on the City of Seattle following a Seattle Fault event. The analysis found that the southern portion of the city and its coastal bluffs would sustain the greatest impacts. Hundreds to thousands of buildings within the city could be impacted (University of Washington, 2013). The analysis also found that many landslides outside of mapped hazard areas may occur, impacting transportation routes. These slides could disrupt emergency response operations. Continued heavy rains and flooding would complicate the problem further.

12.8 ISSUES

Landslides are often a secondary hazard related to other natural disasters. Landslide-triggering rainstorms often produce damaging floods. Earthquakes often induce landslides that can cause additional damage. The identification of areas susceptible to landslides is necessary to support grading, building, foundation design, housing density, and other land development regulations in reducing the risk of property damage and personal injury. The most significant effect of landslides in King County is the disruption of transportation and the destruction of private and public property. Important issues associated with landslides in the planning area include the following:

- There are existing homes in landslide risk areas throughout the County. The degree of vulnerability of these structures depends on the codes and standards to which the structures were constructed.
- Although known landslide hazard areas and steep slopes are subject to regulation under critical area ordinances, continued development pressures could lead to more homes in landslide risk areas. Furthermore, landslides may occur that threaten people and property outside of these mapped areas.
- Mapping and assessment of landslide hazards are constantly evolving. As new data and science become available, assessments of landslide risk should be reevaluated.
- The impact of climate change on landslides is uncertain. Climate change impacts that alter vegetation patterns, increase the occurrence of wildfires or alter precipitation patterns may increase exposure to landslide risks.
- Landslides may cause negative environmental consequences, including water quality degradation.

- The risk associated with the landslide hazard overlaps the risk associated with other hazards such as earthquake, flood and wildfire. This provides an opportunity to seek mitigation alternatives that can reduce risk for multiple hazards.
- Facilities that contain hazardous materials located in landslide hazard areas may present additional risks for the planning area. Future analysis should assess the exposure and vulnerability of such facilities to landslide hazards.
- Mine hazard areas constitute additional geological hazards in the planning area. Future analyses should assess the exposure and vulnerability of the planning area to these sites. According to critical areas guidance, factors that should considered in such an assessment include proximity to development, depth from ground surface to the mine working, and geological material (Washington State Department of Community, Trade and Economic Development, 2007).
- Additional studies should be performed that assess the risks from seismically induced landslides in the planning area.
- Numerous geological maps published since the 1990s cover portions of the planning area. This updated data may not be reflected in the risk analysis. The numerous landslide events in the planning area since 1990 are also unlikely to be included in the data set used for this analysis.
- LIDAR imagery allows for dramatically greater resolution in delineating landslide features and was not available in the 1990s. A simple, advisory analysis using data derived from LIDAR was performed for this plan, but a more sophisticated analysis should be performed.
- Currently available maps do not indicate run-out (where a landslide might go). Current maps show the area that might be unstable, but do not offer a complete picture of areas at risk.
- As of the completion of this planning effort, King County was convening a landslide task force to look at the landslide risk within King County more in depth. Products and recommendations from this task force should be considered in future updates to this plan.

CHAPTER 13.

SEVERE WEATHER

13.1 GENERAL BACKGROUND

Severe weather refers to any dangerous meteorological phenomena with the potential to cause damage, serious social disruption, or loss of human life. It includes thunderstorms, hail storms, damaging winds, tornadoes and excessive heat.

Severe weather can be categorized into two groups: systems that form over wide geographic areas are classified as general severe weather; those with a more limited geographic area are classified as localized severe weather. Severe weather, technically, is not the same as extreme weather, which refers to unusual weather events at the extremes of the historical distribution for a given area.

The most common severe weather events that impact the planning area are thunderstorms, damaging winds and hail storms. These types of severe weather, as well as excessive heat events and tornadoes, are described in the following sections. Flooding issues associated with severe weather are discussed in Chapter 11..

13.1.1 Extreme Heat

Excessive heat events are defined by the U.S. EPA as "summertime weather that is substantially hotter and/or more humid than average for a location at that time of year" (U.S. EPA, 2006). Heat waves are excessive heat events that typically last two or more days (CDC, 2014b). Because extreme heat is relative to the usual weather in a region, criteria that define an extreme heat event may differ among jurisdictions and with the time of year. In general, extreme heat events can be characterized by temperatures greater than 90°F, warm stagnant air masses and consecutive nights with higher-than-usual minimum temperatures (CDC, 2009).

Heat Index

Extreme heat events are often a result of more than ambient air temperature. Heat index tables (see Figure 13 -50) are commonly used to provide information about how hot it feels based on several meteorological conditions. Heat index values are for shady, light wind conditions; exposure to full sunshine can increase heat index values by up to 15°F. Strong winds with very hot, dry air also can be extremely hazardous (NWS, 2014b).

DEFINITIONS

Extreme Heat Event/Heat Wave—Summertime weather that is substantially hotter and/or more humid than average for a location at that time of year. Typically a heat wave lasts two or more days.

Severe Local Storm—Small-scale atmospheric systems, including tornadoes, thunderstorms, and windstorms. These storms may cause a great deal of destruction and even death, but their impact is generally confined to a small area. Typical impacts are on transportation infrastructure and utilities.

Thunderstorm—A storm featuring heavy rains, strong winds, thunder and lightning, typically about 15 miles in diameter and lasting about 30 minutes. Hail and tornadoes are also dangers associated with thunderstorms. Lightning is a serious threat to human life. Heavy rains over a small area in a short time can lead to flash flooding.

Tornado—Funnel clouds that generate winds up to 500 miles per hour. They can affect an area up to three-quarters of a mile wide, with a path of varying length. Tornadoes can come from lines of cumulonimbus clouds or from a single storm cloud. They are measured using the Fujita Scale, ranging from F0 to F5.

Windstorm—A storm featuring violent winds. Southwesterly winds are associated with strong storms moving onto the coast from the Pacific Ocean. Southern winds parallel to the coastal mountains are the strongest and most destructive winds. Windstorms tend to damage ridgelines that face into the winds.

NOAA's National Weather Service

Heat Index

Temperature (°F)

Relative Humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

Caution   Extreme Caution   Danger   Extreme Danger

Figure 13-50. Heat Index Table

Heat Islands

Extreme heat events may be exacerbated in urban areas, where reduced air flow, reduced vegetation and increased generation of waste heat can contribute to temperatures that are several degrees higher than in surrounding rural or less urbanized areas. When urban buildings, roads and other infrastructure replace open land and vegetation, surfaces that were once permeable and moist become impermeable and dry. These changes cause urban areas to become warmer than the surrounding areas, serving as contiguous regions of higher temperatures. This phenomenon is known as urban heat island effect. Heat islands can affect communities by increasing peak summer energy demand, air pollution, greenhouse gas emissions, heat-related illness and death, and water quality degradation.

13.1.2 Thunderstorms

A thunderstorm is a rain event that includes thunder and lightning. A thunderstorm is classified as "severe" when it contains one or more of the following: hail with a diameter of three-quarter inch or greater, winds gusting in excess of 50 knots (57.5 mph), or tornado. Approximately 10 percent of the 100,000 thunderstorm that occur nationally every year are classified as severe (NOAA, 2014).

Three factors cause thunderstorms to form: moisture, rising unstable air (air that keeps rising when disturbed), and a lifting mechanism to provide the disturbance. The sun heats the surface of the earth, which warms the air above it. If this warm surface air is forced to rise (hills or mountains can cause rising motion, as can the interaction of warm air and cold air or wet air and dry air) it will continue to rise as long as it weighs less and stays warmer than the air around it. As the air rises, it transfers heat from the surface of the earth to the upper levels of the atmosphere (the process of convection). The water vapor it contains begins to cool and it condenses into a cloud. The cloud eventually grows upward into areas where the temperature is below freezing. Some of the water vapor turns to ice and some of it turns into

water droplets. Both have electrical charges. Ice particles usually have positive charges, and rain droplets usually have negative charges. When the charges build up enough, they are discharged in a bolt of lightning, which causes the sound waves we hear as thunder. Thunderstorms have three stages (see Figure 13 -51):

– The *developing stage* of a thunderstorm is marked by a cumulus cloud that is being pushed upward by a rising column of air (updraft). The cumulus cloud soon looks like a tower (called towering cumulus) as the updraft continues to develop. There is little to no rain during this stage but occasional lightning. The developing stage lasts about 10 minutes.

– The thunderstorm enters the *mature stage* when the updraft continues to feed the storm, but precipitation begins to fall out of the storm, and a downdraft begins (a column of air pushing downward). When the downdraft and rain-cooled air spread out along the ground, they form a gust front, or a line of gusty winds. The mature stage is the most likely time for hail, heavy rain, frequent lightning, strong winds, and tornadoes. The storm occasionally has a black or dark green appearance.

– Eventually, a large amount of precipitation is produced and the updraft is overcome by the downdraft beginning the *dissipating stage*. At the ground, the gust front moves out a long distance from the storm and cuts off the warm moist air that was feeding the thunderstorm. Rainfall decreases in intensity, but lightning remains a danger.

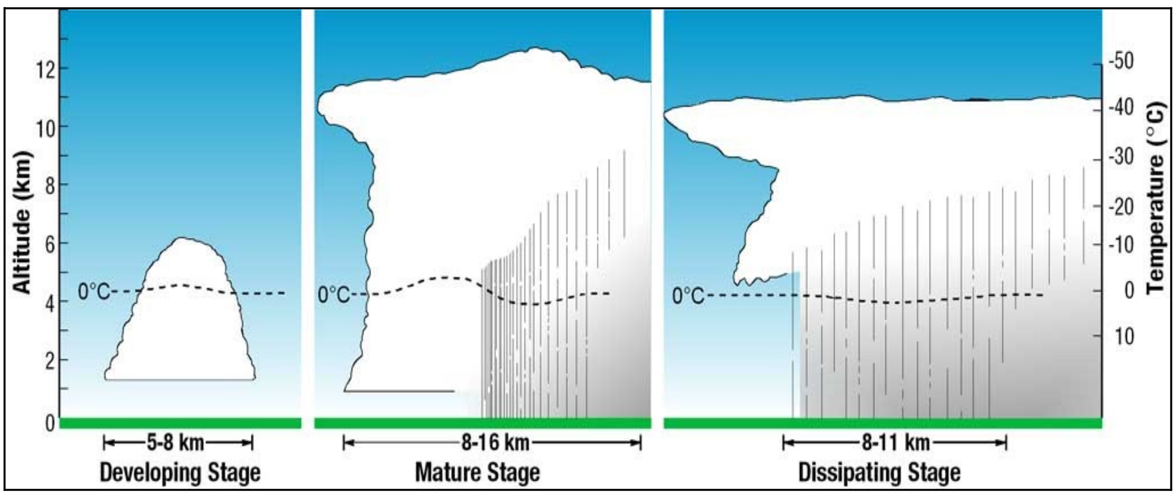


Figure 13-51. The Thunderstorm Life Cycle

There are four types of thunderstorms:

- **Single-Cell Thunderstorms—**Single-cell thunderstorms usually last 20 to 30 minutes. A true single-cell storm is rare, because the gust front of one cell often triggers the growth of another. Most single-cell storms are not usually severe, but a single-cell storm can produce a brief severe weather event. When this happens, it is called a pulse severe storm.

- **Multi-Cell Cluster Storm—**A multi-cell cluster is the most common type of thunderstorm. The multi-cell cluster consists of a group of cells, moving as one unit, with each cell in a different phase of the thunderstorm life cycle. Mature cells are usually found at the center of the cluster and dissipating cells at the downwind edge. Multi-cell cluster storms can produce moderate-size hail, flash floods and weak tornadoes. Each cell in a multi-cell cluster lasts only about 20 minutes; the multi-cell cluster itself may persist for several hours. This type of storm is usually more intense than a single cell storm.

- **Multi-Cell Squall Line—**A multi-cell line storm, or squall line, consists of a long line of storms with a continuous well-developed gust front at the leading edge. The line of storms can be solid, or there can be gaps and breaks in the line. Squall lines can produce hail up to golf-ball size, heavy rainfall, and weak tornadoes, but they are best known as the producers of strong downdrafts. Occasionally, a strong downburst will accelerate a portion of the squall line ahead of the rest of the line. This produces what is called a bow echo. Bow echoes can develop with isolated cells as well as squall lines. Bow echoes are easily detected on radar but are difficult to observe visually.
- **Super-Cell Storm—**A super-cell is a highly organized thunderstorm that poses a high threat to life and property. It is similar to a single-cell storm in that it has one main updraft, but the updraft is extremely strong, reaching speeds of 150 to 175 miles per hour. Super-cells are rare. The main characteristic that sets them apart from other thunderstorms is the presence of rotation. The rotating updraft of a super-cell (called a mesocyclone when visible on radar) helps the super-cell to produce extreme weather events, such as giant hail (more than 2 inches in diameter), strong downbursts of 80 miles an hour or more, and strong to violent tornadoes.

Lightning occurs in all thunderstorms. There are two main types of lightning: intra-cloud lightning and cloud-to-ground lightning. Cloud-to-ground lightning consists of at least one leader and at least one return stroke. The leader initiates the first phase of the a lightning discharge, while a return stroke moves upward along a lightning channel from the ground to the cloud (National Weather Service, 2014).

13.1.3 Hail Storms

Hail occurs when updrafts in thunderstorms carry raindrops upward into extremely cold areas of the atmosphere where they freeze into ice. Recent studies suggest that super-cooled water may accumulate on frozen particles near the back-side of a storm as they are pushed forward across and above the updraft by the prevailing winds near the top of the storm. Eventually, the hailstones encounter downdraft air and fall to the ground.

Hailstones grow two ways: by wet growth or dry growth. In wet growth, a tiny piece of ice is in an area where the air temperature is below freezing, but not super cold. When the tiny piece of ice collides with a super-cooled drop, the water does not freeze on the ice immediately. Instead, liquid water spreads across tumbling hailstones and slowly freezes. Since the process is slow, air bubbles can escape, resulting in a layer of clear ice. Dry growth hailstones grow when the air temperature is well below freezing and the water droplet freezes immediately as it collides with the ice particle. The air bubbles are “frozen” in place, leaving cloudy ice.

Hailstones can have layers like an onion if they travel up and down in an updraft, or they can have few or no layers if they are “balanced” in an updraft. One can tell how many times a hailstone traveled to the top of the storm by counting its layers. Hailstones can begin to melt and then re-freeze together, forming large and very irregularly shaped hail.

13.1.4 Damaging Winds

Damaging winds are classified as those exceeding 60 mph. Damage from such winds accounts for half of all severe weather reports in the lower 48 states. Wind speeds can reach up to 100 mph and can produce a damage path extending for hundreds of miles. Isolated wind events in mountainous regions have more localized effects. Windstorms in Washington typically occur from October through March (Washington Emergency Management, 2010). There are seven types of damaging winds:

- **Straight-line winds**—Any thunderstorm wind that is not associated with rotation; this term is used mainly to differentiate from tornado winds. Most thunderstorms produce some straight-line winds as a result of outflow generated by the thunderstorm downdraft.
- **Downdrafts**—A small-scale column of air that rapidly sinks toward the ground.
- **Downbursts**—A strong downdraft with horizontal dimensions larger than 2.5 miles resulting in an outward burst or damaging winds on or near the ground. Downburst winds may begin as a microburst and spread out over a wider area, sometimes producing damage similar to a strong tornado. Although usually associated with thunderstorms, downbursts can occur with showers too weak to produce thunder.
- **Microbursts**—A small concentrated downburst that produces an outward burst of damaging winds at the surface. Microbursts are generally less than 2.5 miles across and short-lived, lasting only 5 to 10 minutes, with maximum wind speeds up to 168 mph. There are two kinds of microbursts: wet and dry. A wet microburst is accompanied by heavy precipitation at the surface. Dry microbursts, common in places like the high plains and the intermountain west, occur with little or no precipitation reaching the ground.
- **Gust front—**A gust front is the leading edge of rain-cooled air that clashes with warmer thunderstorm inflow. Gust fronts are characterized by a wind shift, temperature drop, and gusty winds out ahead of a thunderstorm. Sometimes the winds push up air above them, forming a shelf cloud or detached roll cloud.
- **Derecho**—A derecho is a widespread thunderstorm wind caused when new thunderstorms form along the leading edge of an outflow boundary (the boundary formed by horizontal spreading of thunderstorm-cooled air). The word “derecho” is of Spanish origin and means “straight ahead.” Thunderstorms feed on the boundary and continue to reproduce. Derechos typically occur in summer when complexes of thunderstorms form over plains, producing heavy rain and severe wind. The damaging winds can last a long time and cover a large area.
- **Bow Echo**—A bow echo is a linear wind front bent outward in a bow shape. Damaging straight-line winds often occur near the center of a bow echo. Bow echoes can be 200 miles long, last for several hours, and produce extensive wind damage at the ground.

Windstorms can result in collapsed or damaged buildings, damaged or blocked roads and bridges, damaged traffic signals, streetlights and parks, and other damage. They can also cause direct losses to buildings, people, and vital equipment. There are direct consequences to the local economy resulting from windstorms related to both physical damage and interrupted services.

Wind pressure can create a direct and frontal assault on a structure, pushing walls, doors, and windows inward. Conversely, passing currents can create lift and suction forces that act to pull building components and surfaces outward. As positive and negative forces impact a building’s doors, windows and walls, the result can be roof or building component failures and considerable structural damage. The effects of winds are magnified in the upper levels of multi-story structures.

Debris carried along by extreme winds can contribute directly to loss of life and indirectly to the failure of protective building envelopes. Falling trees and branches can damage buildings, power lines, and other property and infrastructure. Tree limbs breaking in winds of only 45 mph can be thrown over 75 feet, so overhead power lines can be damaged even in relatively minor windstorm events. During wet winters, saturated soils cause trees to become less stable and more vulnerable to uprooting from high winds. Utility lines brought down by summer thunderstorms have also been known to cause fires, which start in dry roadside vegetation. Electric power lines falling down to the pavement create the possibility of lethal electric shock.

Downed trees and power lines, and damaged property also can be major hindrances to emergency response and disaster recovery. Emergency response operations can be complicated when roads are blocked or when power supplies are interrupted. Industry and commerce can suffer losses from interruptions in electric service and from extended road closures.

13.1.5 Tornado

A tornado is a violently rotating column of air extending between, and in contact with, a cloud and the surface of the earth. As shown in Figure 13 -52, Washington has a relatively low risk compared to states in the Midwestern and Southern U.S. Washington has experienced tornadoes on occasion. Some have produced significant damage, injury or death. Washington's tornadoes can be formed in association with large Pacific storms arriving from the west. Most of them, however, are caused by intense local thunderstorms. These storms also produce lightning, hail and heavy rain, and are more common during the warm season from April to October.

Tornadoes are often (but not always) visible as a funnel cloud. On a local-scale, tornadoes are the most intense of all atmospheric circulations and wind can reach destructive speeds of more than 300 mph. A tornado's vortex is typically a few hundred meters in diameter, and damage paths can be up to 1 mile wide and 50 miles long. Tornadoes can occur throughout the year at any time of day but are most frequent in the spring during the late afternoon. Figure 13 -53 illustrates the potential impacts and damage from tornadoes of different magnitudes.

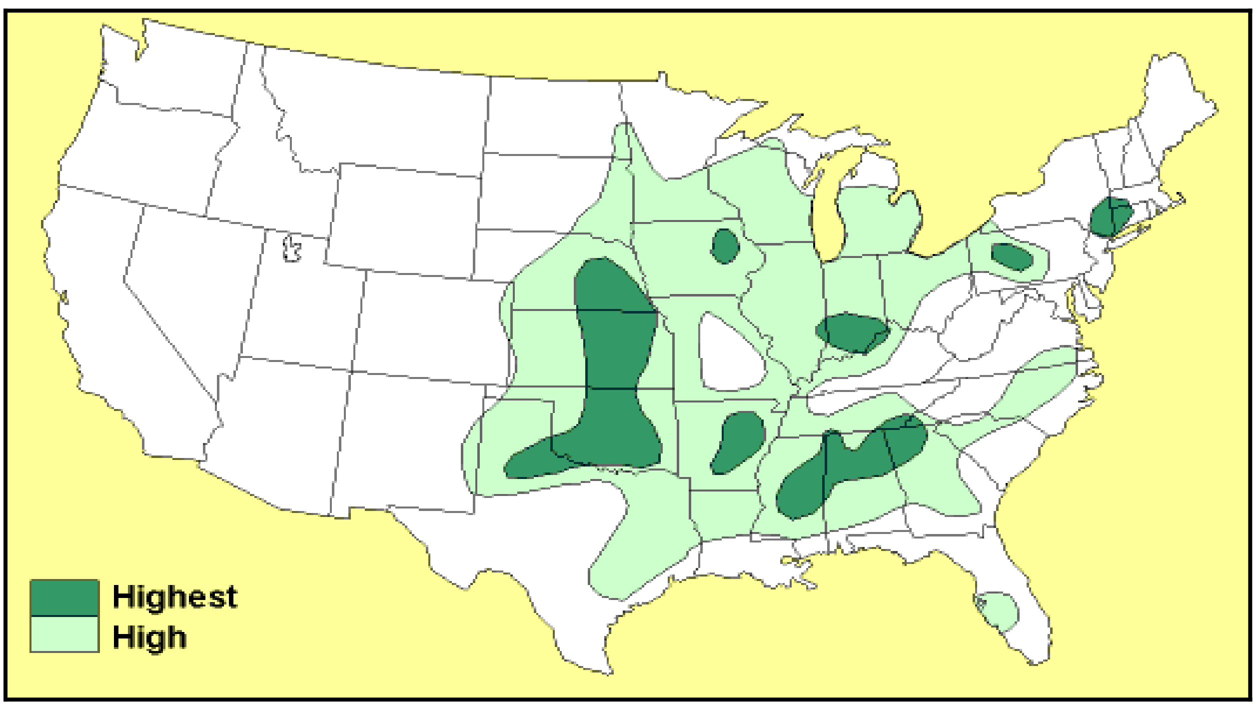
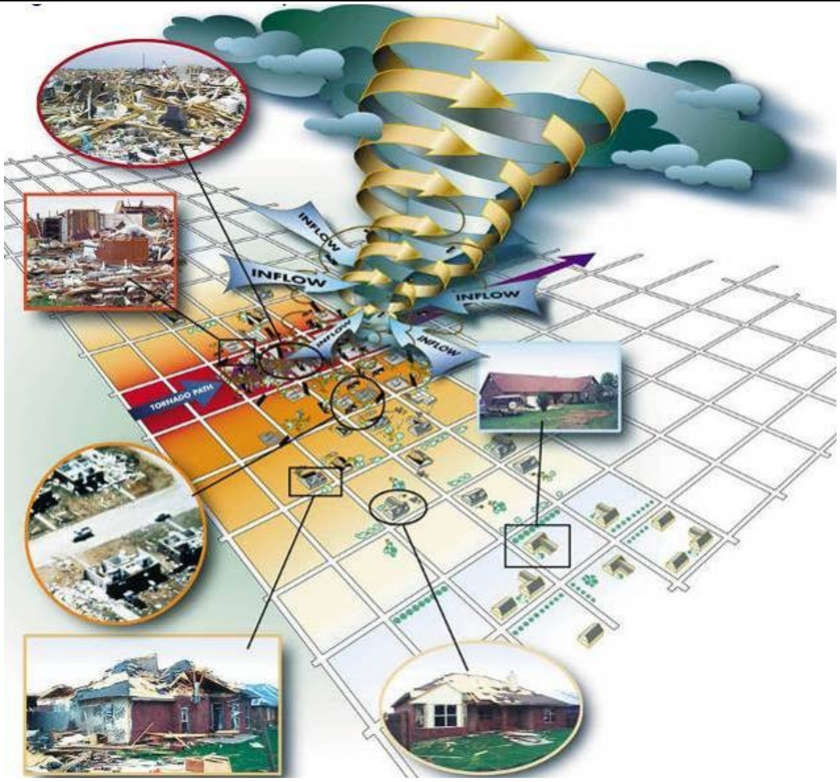


Figure 13-52. Tornado Risk Areas in the United States



Managing Risk	Damage Color Code	Description of Damage
The Threat to Property and Personal Safety Can Be Minimized Through Compliance With Up-To-Date Model Building Codes and Engineering Standards		Some damage can be seen to poorly maintained roofs. Unsecured light-weight objects, such as trash cans, are displaced.
		Minor damage to roofs and broken windows occur. Larger and heavier objects become displaced. Minor damage to trees and landscaping can be observed.
Property and Personal Protection Can Be Improved Through Wind Hazard Mitigation Techniques Not Normally Required by Current Building Codes		Roofs are damaged, including the loss of shingles and some sheathing. Manufactured homes, on nonpermanent foundations can be shifted off their foundations. Trees and landscaping either snap or are blown over. Medium-sized debris becomes airborne, damaging other structures.
		Roofs and some walls, especially unreinforced masonry, are torn from structures. Small ancillary buildings are often destroyed. Manufactured homes on nonpermanent foundations can be overturned. Some trees are uprooted.
Personal Protection Can Only Be Achieved Through Use of a Specially Designed Extreme Wind Refuge Area, Shelter, or Safe Room		Well constructed homes, as well as manufactured homes, are destroyed, and some structures are lifted off their foundations. Automobile-sized debris is displaced and often tumbles. Trees are often uprooted and blown over.
		Strong frame houses and engineered buildings are lifted from their foundations or are significantly damaged or destroyed. Automobile-sized debris is moved significant distances. Trees are uprooted and splintered.

Figure 13-53. Potential Impact and Damage from a Tornado

13.2 HAZARD PROFILE

13.2.1 Past Events

Table 13 -69 summarizes severe weather events in the planning area since 1996, as recorded by the National Oceanic and Atmospheric Administration (NOAA).

TABLE 13-69.
PAST SEVERE WEATHER EVENTS IMPACTING PLANNING AREA

Date	Type	Deaths or Injuries	Property Damage
09/03/1996	Flood	0	$0
Description: *A couple of thunderstorms moved through Puget Sound, knocking out power, and forcing the closure of some roads due to flooding. There was also some marble sized hail. Most of the problems were due to urban flooding. Traffic was slowed to a crawl in most areas because of standing water and several apartments in Bellevue had flooded. Reports of a half an inch in 20 min and three quarters of an inch of rain in 30 min were common.*			
10/15/1996	Lightning	0	$95,000
Description: *Lightning was the probable cause to a house fire that caused $95,000 in damage.*			
11/30/1996	Lightning	1 injury	$0
Description: *A woman suffered burns to her fingers when lightning struck a telephone line. Lightning also knocked out power in several areas of Bellevue when it struck transformers.*			
12/10/1996	Lightning	0	$350,000
Description: **Lightning damaged a home, struck another mobile home and struck a tree near Lake Ballinger.**			
12/29/1996	Heavy Rain	0	$31.5 million
Description: *Overall, the total damage from the storm that lasted from December 26 – 31, caused about $315 million in both insured and uninsured damage (in all of WA). Although not all directly caused by the weather (some indirect) the storms claimed 16 lives and sparked a state of emergency in 30 counties. Seattle normally averages 1.44" of precipitation between Dec. 26 and Jan 2nd. This winter it received 8.35" during those eight days. The total number of customers without power at one time was nearly 300,000 and some people went a week without power. The damage affected people for weeks. In Seattle the Magnolia bridge had supports wiped out by mudslides and forced evacuations of 85 homes in the area due to mudslides and sinkholes..*			
01/02/1997	Lightning	0	$0
Description: *Lightning struck a home knocking gutters off, blew the electric box out of the wall, left burn marks across the floor and melted a sewing machine. The lightning also affected two other homes, disabling a garage door and blacking out a computer.*			
04/03/1997	Lightning	1 injury	$0
Description: *A woman holding an umbrella was struck by lightning.*			
06/03/1997	Funnel Cloud	0	$0
Description: *A spotter observed a small funnel cloud.*			
07/05/1997	Lightning	2 injuries	$0
Description: *Two people, a 30 year old woman and a 24 year old man, suffered minor injuries after being struck by lightning. Both were indirect hits, with one of the strikes travelling through a chain link fence before zapping the woman.*			
08/06/1997	Lightning	1 injury	$0
Description: *Two people were struck by lightning. Only one was injured with burns on his leg. Lightning also damaged a church furnace and split trees. Power was knocked out to about 1000 customers.*			

TABLE 13-69.
PAST SEVERE WEATHER EVENTS IMPACTING PLANNING AREA

Date	Type	Deaths or Injuries	Property Damage
10/04/1997	Lightning	0	$5,000
Description: *A lightning bolt struck a home, blowing an 8 foot hole in the living-room wall. It also damaged a nearby tree.*			
04/08/1998	Lightning	0	0
Description: *Lightning struck a fir tree and a shed. It burned a hole through the roof of the shed and exploded two bags of lawn chemicals.*			
03/01/1999	Heavy Rain	0	$5.5 million
Description: *The heavy rain, which in turn caused flooding and mudslides, over the winter season has caused 18.5 million damage to Washington State roads. The two hardest hit counties were Mason with 10.2 and King with 5.5 million in damage.*			
06/01/1999	Lightning	0	$0
Description: *Lightning struck a tree and damaged about 50 windows in an apartment complex.*			
07/16/1999	Lightning	0	$130,000
Description: *Lightning struck a house and knocked out power to about 8000 homes.*			
08/03/1999	Lightning	2 injuries	$650,000
Description: *Over 1000 lightning strikes were recorded in a four hour period. One man was struck by lightning while standing under a tree, and another man while standing in water next to his boat. At its peak the storm knocked out power to about 20,000 customers.*			
08/30/1999	Hail	0	$0
Description: *A thunderstorm left up to 2 inches of hail on the ground after it was over. There was also a funnel cloud spotted by a NWS employee.*			
11/17/1999	Heavy Rain	0	$85,000
Description: *Heavy rains led to a road being washed out by Issaquah Creek.*			
01/14/2000	Heavy Rain	15 injuries	$0
Description: *More than two dozen vehicles collided on Interstate 5 during a brief, but heavy, rain shower. Traffic was backed up for about 7 miles.*			
02/08/2000	Thunderstorm & Wind	0	$25,000
Description: *A microburst with winds estimated at 50 mph hit West Seattle knocking down a few trees, damaging two homes and a car.*			
06/11/2001	Tornado	0	$0
Description: *A very weak tornado tossed a teacher and a few children into the air. No one was injured.*			
08/21/2001	Heavy Rain	0	$0
Description: *Record rainfall amounts were set in several locations throughout western Washington on the 22nd. Nearly a month's worth of rain (for Aug ~ 1 inch) fell over most of the area with 2 to 5 inches common along the coast and in the mountains. The greatest storm total was 6.38 inches at Finney Creek in the north Cascades. The heavy rains caused a few power outages and flooding of some roads including SR-16. A woman was swept to her death while trying to cross the Quinault River's east fork in Jefferson County.*			
11/13/2001	Heavy Rain	0	$0
Description: *Heavy rain caused several mudslides which closed several roads across western Washington. In a 48 hour period 3-5 inches of rain fell in the interior with 4-8 inches along the coast. Several sites set records for rainfall on Wed Nov 14th - from midnight to midnight, Olympia received 3.64 inches while SeaTac got 2.61 inches. Several buildings were flooded and small mudslides flowed over a few homeowners property, but no significant damage was reported.*			

**TABLE 13-69.
PAST SEVERE WEATHER EVENTS IMPACTING PLANNING AREA**

Date	Type	Deaths or Injuries	Property Damage
09/08/2003	Heavy Rain	0	$5,000
Description: *After about a month with little or no rainfall, a few heavy showers opened up over eastern King and Snohomish counties. Up to 1.5 inches fell in Kirkland, where a couple of homes and a church were flooded. In Duvall, 3500 customers lost power due to toppled trees.*			
10/20/2003	Heavy Rain	0	$100,000
Description: *An all-time daily record rainfall total was set at SeaTac Airport with 5.02 inches. Almost all reporting stations had at least 2 inches of rain in the 24 hour period from midnight to midnight. In all, nearly 50 homes spread over several counties suffered damage from minor flooding especially in basements and garages. Traffic snarls were common as many roads throughout the region were temporarily closed. The national parks and forests suffered fairly extensive damage to several bridges and many trails or the roads that lead to the trails.*			
02/06/2004	Lightning	0	$0
Description: *An airport ramp worker was dazed after lightning struck the plane he was attending at SeaTac Airport.*			
05/27/2004	Funnel Cloud	0	$0
Description: *No description available.*			
08/22/2004	Heavy Rain	0	$50,000
Description: *Heavy rain flooded a Qwest copper cable, which disrupted phone service to 1,500 customers. 26 homes in Seattle's Madison valley neighborhood suffered damage, when a storm water overflow tank backed up.*			
02/04/2005	Lightning	0	$1,000
Description: *A lightning strike caused a small fire on the roof of a gas station.*			
03/16/2005	Funnel Cloud	0	$0
Description: *No description available.*			
12/24/2005	Heavy Rain	0	$10,000
Description: *Heavy rain caused a local creek to flood and damage 3 local businesses in north Seattle.*			
01/05/2006	Heavy Rain	0	$800,000
Description: *The Governor declared a state of emergency after rain, at times heavy, over a period of about 10 days, caused over 7 million in damage, mainly to transportation infrastructure throughout western Washington. Mudslides closed parts of I-5 near the Pierce-Thurston county line, part of Highway 20 about a half mile east of Concrete, Highway 107 near Raymond, and Highway 166 near Port Orchard - where 3 cars crashed in the mud. In King County, there were 19 road closures from water over the roadway. Many homes had flooded basements or crawlspaces.*			
03/10/2006	Hail	0	$0
Description: *A thunderstorm briefly dumped 1 inch hail in Redmond.*			
11/04/2006	Flood	0	$11.1 million
Description: *A strong, warm and very wet Pacific weather system brought copious amounts of rainfall to Washington from November 2 through 7, with subsequent major flooding through November 11. This storm produced rain amounts of 10 to 38 inches in the Cascades and Olympics and 4 to 10 inches in western Washington lowlands. Floods occurred at 34 forecast points on 25 rivers. There were 22 locations with major flooding or greater. There were 20 record floods. Widespread and excessive urban and small stream flooding also occurred. 11 counties were declared disaster areas. A tally had 104 homes destroyed, 206 homes with major damage, and 572 received minor damage.*			

TABLE 13-69.
PAST SEVERE WEATHER EVENTS IMPACTING PLANNING AREA

Date	Type	Deaths or Injuries	Property Damage
12/14/2006	Heavy Rain/Flash Flood	1 death	$1.75 million
Description: *A strong rain and wind storm on Dec 14 – 15 initially brought 1 to 2 inches of heavy rainfall to parts of western Washington, producing areas of urban and small stream flooding and overwhelming drainage systems. Widespread strong damaging winds followed. In western Washington, peak winds reached 80 to 90 mph along the coast and 60 to 75 mph elsewhere. A few locations had gusts as high 85 mph in the interior. Mountain areas recorded peak wind speeds in excess of 100 mph. The wind storm blew down thousands of trees and knocked power out to close to 1.5 million customers. There were four fatalities as a direct result of the storm and 11 indirect fatalities following the storm: Three people in western Washington were killed by fallen trees; one person drowned in Seattle when a basement filled with rain runoff; two people were electrocuted by downed power lines and one man died after his home burned apparently started by a candle used for light. 36 people were directly injured by the wind storm. Another 275 people in King county were treated for carbon monoxide poisoning.*			
07/13/2007	Lightning	0	$5,000
Description: *Lightning struck a home in Kirkland causing minor damage.*			
12/03/2007	Heavy Rain	0	$12 million
Description: *Flooding occurred on the Skykomish and Snoqualmie Rivers and Issaquah Creek. Significant urban and small stream flooding occurred in King County as 3 to 8 inches of rain fell over the area. A storm system initially generated lowland snow in western Washington and later created strong winds in the coastal region and avalanches in the Cascades. Four apartment buildings were evacuated in North Seattle, where some basement apartments had 3 feet of water in them. About 30 people were evacuated from apartments in Woodinville. Many roads were closed. About 20 roads were damaged. Nearly 5 inches of rain fell at SeaTac airport. Nathan Hale High School in north Seattle was closed for a week due to water damage from Thornton Creek. Homes and businesses had water damage.*			
05/17/2008	Heat	2 indirect deaths, 14 indirect injuries	$0
Description: *Western Washington had its first hot spell of the year following below normal spring temperatures. The heat helped push mountain snow melt streams higher (below flood levels) with swift running and cold water temperatures. This combination led to people seeking relief from the heat by heading to these swift running streams. There were two indirect fatalities due to the heat. Both are missing and likely drowned. One kayaker spilled into the Green River and disappeared. One of four rafters who were thrown into the Green River when their raft flipped disappeared (King County).*			
06/06/2008	Funnel Cloud	0	$0
Description: *A January type storm hit western Washington with strong winds and 2 funnel clouds. Winds gusting to 45 mph knocked out power to nearly 35,000 customers. One fallen tree struck three mobile homes in Purdy. South Kitsap high school students got the day off because of a power outage at the school. The final evening run of the Port Townsend - Keystone ferry was canceled. Funnel cloud reached about half way toward the ground.*			
07/02/2008	Hail	0	$0
Description: *Lots of lightning and small hail was reported from the afternoon of the 2nd through the early morning hours of the 3rd.*			
08/25/2008	Funnel Cloud	0	$0
Description: *Two funnel clouds were spotted. One over Lake Washington, and another near Black Diamond.*			
11/12/2008	Heavy Rain	0	$100,000
Description: *Heavy rain caused flooding on 15 western Washington rivers, with eight river forecast points reaching major flood stage. Major flooding on the Snoqualmie River.*			

**TABLE 13-69.
PAST SEVERE WEATHER EVENTS IMPACTING PLANNING AREA**

Date	Type	Deaths or Injuries	Property Damage
01/07/2009	Heavy Rain	0	$14 million
Description: *Rainfall of 8-20 inches in the mountains and 1 to 9 inches in the lowlands occurred Jan 6 – 8. Record flooding occurred on the Snoqualmie, Tolt, and North Fork Stillaguamish Rivers. Major flooding occurred on 18 rivers and 21 forecast points. Surveys found an estimated 497 residences that were destroyed or suffered major damage, and another 2,340 residences that needed repairs. Over 44,000 people were evacuated. The cities of Snoqualmie, Carnation, Duvall and Fall City flooded. Issaquah Creek flooded some residences and businesses. It also eroded part of the riverbank, which caused a guest house to fall into the creek. About 40 King County roads were closed. In Pacific, about 1000 people evacuated due to flooding from releases from the Mud Mountain dam.*			
04/28/2009	Funnel Cloud	0	$0
Description: *A funnel cloud was spotted near Maple Valley for a few minutes and photographed.*			
07/27/2009	Excessive Heat	1 death	$0
Description: *Strong high pressure aloft led to a major heat event for Western Washington. The average temperature for July 2009 at Seattle-Tacoma airport was 69.5 degrees, the warmest July on record for the airport, and tying the record for the warmest July on record in Seattle. Many record high temperatures were broken, including 103ºF at Seattle-Tacoma airport, 104ºF at Olympia and 96ºF at Bellingham. A heat related death occurred when a 66 year old male died in Seattle. The downtown Bremerton library closed for two days due to excessive heat. Some University of Washington libraries closed and several classes were held outside due to the lack of air conditioning in classrooms.*			
09/06/2009	Lightning	0	$20,000
Description: *Lightning struck a tree next to a home, causing damage to the home's siding and electronics inside.*			
05/08/2010	Funnel Cloud	0	$0
Description: *Some bicycles were tossed and a tent blew apart at Genesee Park in the Rainier Valley of Seattle.*			
06/09/2010	Funnel Cloud	0	$0
Description: *A spotter saw a small funnel cloud east of Enumclaw. It was brief and spotter could not see if it touched the ground due to the trees.*			
12/12/2010	Heavy Rain	0	$3 million
Description: *There was major flooding along the Snoqualmie River. Westside Hwy on Vashon island was closed due to a portion of the road sinking. Some basements flooded in Newcastle. Several roads around North Bend and Carnation were closed due to flooding.*			
12/14/2010	Thunderstorm & Wind	0	$25,000
Description: *A squall line produced outflow winds with gusts between 45 and 70 mph. About 8600 Seattle City Light customers lost power. About 300 homes in the Sammamish area lost power. A Maple valley lumber storage building had its roof ripped off.*			
01/16/2011	Heavy Rain	1	$20,000
Description: *A DOT worker was killed when a tree fell on Highway 203 south of Carnation. Several mudslides blocked roads. The Snoqualmie Falls golf course and parts of Highway 202 were flooded.*			
07/13/2012	Lightning	1 injury	$100,000
Description: *A lightning strike cause minor damage to a home and minor injuries to the homeowner when he was blown across the room. After the lightning strike, a fire started, which caused nearly $100,000 damage to the house.*			
01/09/2013	Debris Flow	0	$5,000
Description: *Two mudslides between Jan 8th and 9th caused minor damage in King and Whatcom counties. A road was partially blocked and minivan damaged when a mudslide occurred just south of Alki Beach.*			
05/13/2013	Thunderstorm, Wind	0	$25,000
Description: *A tree and power lines fell across cars in a parking lot at Green River Community College in Auburn. Classes were canceled for the rest of the day due to a power outage*			

TABLE 13-69.
PAST SEVERE WEATHER EVENTS IMPACTING PLANNING AREA

Date	Type	Deaths or Injuries	Property Damage
07/17/2013	Lightning	0	$5,000
Description: *One lightning strike damaged a transformer, which knocked out power to customers in Shoreline.*			
07/31/2013	Lightning	0	$10,000
Description: *Thunderstorms damaged two homes and an underground pipeline near Sammamish.*			
09/05/2013	Heavy Rain	0	$10,000
Description: *Heavy rain caused a sinkhole that damaged a road in Burien.*			

Source: http://www.ncdc.noaa.gov/stormevents/choosedates.jsp?statefips=53%2CWASHINGTON

13.2.2 Location

Severe weather events have the potential to happen anywhere in the planning area. Communities in low-lying areas next to streams or lakes are more susceptible to flooding. Wind events are most damaging to areas that are heavily wooded and areas with exposed property, major infrastructure, and above ground utility lines. The distribution of average weather conditions over the planning area is shown in Figure 6 -11 through Figure 6 -14.

13.2.3 Frequency

The severe weather events for King County shown in Table 13 -69 are often related to high winds, heavy rain or lightning associated with storms. The planning area can expect to experience exposure to some type of severe weather event at least annually. In 18 years, the county has experienced 57 severe weather events with an average of 3 events per year.

According to the Washington State Hazard Mitigation Plan, King County is vulnerable to high winds. The County is likely to experience at least one high wind event per year. Washington averaged three tornadoes per year between 1991 and 2010, none with a rating of EF3 or greater. The state ranks low in the U.S. for average annual tornadoes per square mile—only Oregon, Nevada, Utah and Alaska have fewer yearly tornadoes per area than Washington’s 0.4 per 10,000 square miles (NOAA, 2014b). Lightning strikes occur occasionally in the planning area, although much less frequently than in other parts of the country. Since 1996, NOAA reports 19 lightning strikes in King County, with 7 injuries, no deaths, and $925,500 in damage. Flooding as a result of severe weather occurs annually within the planning area (see Chapter 11). Only two instances of extreme heat events are listed for the planning area between 1996 and 2013; however, this data likely underestimates the occurrence of such events in the planning area. Extreme heat events can occur several times per year, especially in the summer.

13.2.4 Severity

The most common problems associated with severe storms are immobility and loss of utilities. Fatalities are uncommon, but can occur. Roads may become impassable due to flooding, downed trees or a landslide. Power lines may be downed due to high winds, and services such as water or phone may not be able to operate without power. Lightning can cause severe damage and injury.

Windstorms can be a frequent problem in the planning area and have been known to cause damage to utilities. The predicted wind speed given in wind warnings issued by the National Weather Service is for a one-minute average; gusts may be 25 to 30 percent higher. Lower wind speeds typical in the lower

valleys are still high enough to knock down trees and power lines and cause other property damage. Mountainous sections of the County experience much higher winds under more varied conditions.

Tornadoes are potentially the most dangerous of local storms, but they are not common in the planning area. If a major tornado were to strike within the populated areas of the county, damage could be widespread. Businesses could be forced to close for an extended period or permanently, fatalities could be high, many people could be homeless for an extended period, and routine services such as telephone or power could be disrupted. Buildings may be damaged or destroyed.

The severity of an extreme heat event depends on how early the event occurs in the summer and the number of consecutive days it lasts (EPA, 2006). Urban heat island effect can exacerbate the severity of an extreme heat event.

13.2.5 Warning Time

Meteorologists can often predict the likelihood of a severe storm or other severe weather event. This can give several days of warning time. However, meteorologists cannot predict the exact time of onset or severity of the storm. Some storms may come on more quickly and have only a few hours of warning time. The Seattle Office of the National Weather Service monitors weather stations and issues watches and warnings when appropriate to alert government agencies and the public of possible or impending weather events. The watches and warnings are broadcast over NOAA weather radio and are forwarded to the local media for retransmission using the Emergency Alert System. NWS and NOAA also issue outlooks, watches, warnings and advisory information for extreme heat.

13.3 SECONDARY HAZARDS

The most significant secondary hazards associated with severe local storms are floods, falling and downed trees, landslides and downed power lines. Rapidly melting snow combined with heavy rain can overwhelm both natural and man-made drainage systems, causing overflow and property destruction. Landslides occur when the soil on slopes becomes oversaturated and fails. Excessive heat events can cause failure of motorized systems, such as ventilation systems used to control temperatures inside buildings, if these systems are operating above typical operating standards. Additionally, demand for cooling systems during these events can overload energy systems and result in controlled or unexpected power outages. Fires can occur as a result of lightning strikes.

13.4 EXPOSURE

13.4.1 Population

A lack of data separating severe weather damage from flooding and landslide damage prevented a detailed analysis for exposure and vulnerability. However, it can be assumed that the entire planning area is exposed to some extent to severe weather events. Certain areas are more exposed due to geographic location and local weather patterns. Populations living at higher elevations with large stands of trees or power lines may be more susceptible to wind damage and black out, while populations in low-lying areas are at risk for possible flooding. Populations living in densely populated urban areas are likely to be more exposed to extreme heat events.

13.4.2 Property

According to the King County Assessor, there are 545,846 structures within the census tracts that define the planning area. Most of these buildings are residential. It is estimated that 70 percent of the residential structures were built without the influence of a structure building code with provisions for wind loads. All

of these buildings are considered to be exposed to the severe weather hazard, but structures in poor condition or in particularly vulnerable locations (located on hilltops or exposed open areas) may risk the most damage. The frequency and degree of damage will depend on specific locations.

13.4.3 Critical Facilities and Infrastructure

All critical facilities exposed to flooding (Chapter 11.) are also likely exposed to severe weather. Additional facilities on higher ground may also be exposed to wind damage or damage from falling trees. The most common problems associated with severe weather are loss of utilities. Downed power lines can cause blackouts, leaving large areas isolated. Phone, water and sewer systems may not function. Roads may become impassable due secondary hazards such as landslides.

13.4.4 Environment

The environment is highly exposed to severe weather events. Natural habitats such as streams and trees are exposed to the elements during a severe storm and risk major damage and destruction. Prolonged rains can saturate soils and lead to slope failure. Flooding events caused by severe weather can produce river channel migration or damage riparian habitat. Storm surges can erode beachfront bluffs and redistribute sediment loads.

13.5 VULNERABILITY

13.5.1 Population

Vulnerable populations are the elderly, low income or linguistically isolated populations, people with life-threatening illnesses, and residents living in areas that are isolated from major roads. Power outages can be life threatening to those dependent on electricity for life support. Isolation of these populations is a significant concern. These populations face isolation and exposure during severe weather events and could suffer more secondary effects of the hazard.

Nationally, lighting is one of the leading causes of weather-related fatalities (CDC, 2013). Lightning strikes are far more common in other areas of the country than they are in the Pacific Northwest. The majority of injuries and deaths associated with lighting strikes occur when people are out of doors; however, almost one-third of lightning related injuries occur indoors. Males are five times more likely than females to be struck by lighting and people between the ages of 15 and 34 account for 41 percent of all lightning strike victims (CDC, 2013).

According to the U.S. EPA, the individuals with one or more of the following characteristics are typically at greater risk to the adverse effects of excessive heat events: Individuals with physical or mobility constraints, cognitive impairments, economic constraints, and social isolation. The average summertime mortality for excessive heat events is dependent upon the methodology used to derive such estimates. Certain medical conditions, such as heat stroke, can be directly attributable to excessive heat, while others may be exasperated by excessive heat, resulting in medical emergencies. The U.S. EPA cites two studies that estimate excessive heat attributable deaths in select metropolitan regions in the U.S. based on 1990 population levels (EPA, 2006). Average estimated heat-attributed mortality in Seattle is between 5 (Kalkstein and Greene, 1997) and 96 (Davis et al., 2003).

13.5.2 Property

All property is vulnerable during severe weather events, but properties in poor condition or in particularly vulnerable locations may risk the most damage. Those in higher elevations and on ridges may be more

prone to wind damage. Those that are located under or near overhead lines or near large trees may be damaged in the event of a collapse.

Loss estimates for the severe weather hazard are not based on damage functions, because no such damage functions have been generated. Instead, estimates were developed representing 10 percent, 30 percent and 50 percent of the assessed value of exposed structures. This allows emergency managers to select a range of potential economic impact based on an estimate of the percent of damage to the general building stock. Damage in excess of 50 percent is considered to be substantial by most building codes and typically requires total reconstruction of the structure. Table 13 -70 lists the loss estimates.

13.5.3 Critical Facilities and Infrastructure

Incapacity and loss of roads are the primary transportation failures resulting from severe weather, mostly associated with secondary hazards. Landslides caused by heavy prolonged rains can block roads. High winds can cause significant damage to trees and power lines, blocking roads with debris, incapacitating transportation, isolating population, and disrupting ingress and egress. Of particular concern are roads providing access to isolated areas and to the elderly.

Prolonged obstruction of major routes due to landslides, debris or floodwaters can disrupt the shipment of goods and other commerce. Large, prolonged storms can have negative economic impacts for an entire region.

Severe windstorms and downed trees can create serious impacts on power and above-ground communication lines. Loss of electricity and phone connection would leave certain populations isolated because residents would be unable to call for assistance.

13.5.4 Environment

The vulnerability of the environment to severe weather is the same as the exposure.

13.6 FUTURE TRENDS IN DEVELOPMENT

All future development will be affected by severe storms. The ability to withstand impacts lies in sound land use practices and consistent enforcement of codes and regulations for new construction. The planning partners have adopted the International Building Code in response to Washington State mandates. This code is equipped to deal with the impacts of severe weather events. Land use policies identified in comprehensive plans within the planning area also address many of the secondary impacts (flood and landslide) of the severe weather hazard. To combat the effects of urban heat island effect, communities can implement design standards and urban planning principles that reduce the impacts of excessive heat events. With these tools, the planning partnership is well equipped to deal with future growth and the associated impacts of severe weather.

13.7 SCENARIO

Impacts of severe weather can be significant, particularly when secondary hazards of flood and landslide occur. A worst-case event would involve prolonged high winds accompanied by thunderstorms. Such an event would have both short-term and longer-term effects. Initially, schools and roads would be closed due to power outages caused by high winds and downed tree obstructions. In more rural areas, some subdivisions could experience limited ingress and egress. Prolonged rain could produce flooding, overtopped culverts with ponded water on roads, and landslides on steep slopes. Flooding and landslides could further obstruct roads and bridges, further isolating residents.

TABLE 13-70.
LOSS POTENTIAL FOR SEVERE WEATHER

		Estimated Loss Potential from Severe Weather		
	Total Assessed Value	10% Damage	30% Damage	50% Damage
Algona	$902,612,000	$90,261,200	$270,783,600	$451,306,000
Auburn	$17,992,313,000	$1,799,231,300	$5,397,693,900	$8,996,156,500
Beaux Arts	$60,778,000	$6,077,800	$18,233,400	$30,389,000
Bellevue	$49,163,714,000	$4,916,371,400	$14,749,114,200	$24,581,857,000
Black Diamond	$600,388,000	$60,038,800	$180,116,400	$300,194,000
Bothell	$5,215,897,000	$521,589,700	$1,564,769,100	$2,607,948,500
Burien	$9,165,566,000	$916,556,600	$2,749,669,800	$4,582,783,000
Carnation	$328,410,000	$32,841,000	$98,523,000	$164,205,000
Clyde Hill	$845,586,000	$84,558,600	$253,675,800	$422,793,000
Covington	$2,849,591,000	$284,959,100	$854,877,300	$1,424,795,500
Des Moines	$5,742,226,000	$574,222,600	$1,722,667,800	$2,871,113,000
Duvall	$1,108,322,000	$110,832,200	$332,496,600	$554,161,000
Enumclaw	$2,667,155,000	$266,715,500	$800,146,500	$1,333,577,500
Federal Way	$19,102,220,000	$1,910,222,000	$5,730,666,000	$9,551,110,000
Hunts Point	$160,100,000	$16,010,000	$48,030,000	$80,050,000
Issaquah	$9,587,897,000	$958,789,700	$2,876,369,100	$4,793,948,500
Kenmore	$4,000,207,000	$400,020,700	$1,200,062,100	$2,000,103,500
Kent	$33,182,020,000	$3,318,202,000	$9,954,606,000	$16,591,010,000
Kirkland	$22,202,262,000	$2,220,226,200	$6,660,678,600	$11,101,131,000
Lake Forest Park	$2,214,717,000	$221,471,700	$664,415,100	$1,107,358,500
Maple Valley	$3,129,530,000	$312,953,000	$938,859,000	$1,564,765,000
Medina	$947,196,000	$94,719,600	$284,158,800	$473,598,000
Mercer Island	$6,598,328,000	$659,832,800	$1,979,498,400	$3,299,164,000
Milton	$140,733,000	$14,073,300	$42,219,900	$70,366,500
Newcastle	$2,266,792,000	$226,679,200	$680,037,600	$1,133,396,000
Normandy Park	$1,306,626,000	$130,662,600	$391,987,800	$653,313,000
North Bend	$1,453,593,000	$145,359,300	$436,077,900	$726,796,500
Pacific	$830,743,000	$83,074,300	$249,222,900	$415,371,500
Redmond	$23,234,414,000	$2,323,441,400	$6,970,324,200	$11,617,207,000
Renton	$25,825,586,000	$2,582,558,600	$7,747,675,800	$12,912,793,000
Sammamish	$9,306,835,000	$930,683,500	$2,792,050,500	$4,653,417,500
SeaTac	$7,572,236,000	$757,223,600	$2,271,670,800	$3,786,118,000
Seattle	$212,337,688,000	$21,233,768,800	$63,701,306,400	$106,168,844,000
Shoreline	$11,169,471,000	$1,116,947,100	$3,350,841,300	$5,584,735,500
Skykomish	$74,730,000	$7,473,000	$22,419,000	$37,365,000
Snoqualmie	$2,297,236,000	$229,723,600	$689,170,800	$1,148,618,000
Tukwila	$11,628,108,000	$1,162,810,800	$3,488,432,400	$5,814,054,000
Woodinville	$4,522,687,000	$452,268,700	$1,356,806,100	$2,261,343,500
Yarrow Point	$300,638,000	$30,063,800	$90,191,400	$150,319,000
Unincorporated	$44,641,548,000	$4,648,154,800	$13,404,464,400	$22,340,774,000
Total	0	0	0	0

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.3.5 for a discussion of data limitations.

13.8 ISSUES

Severe local storms are probably the most common widespread hazard. They affect large numbers of people in the planning area when they occur. Severe storms can quickly overwhelm city and county resources. Citizens should be prepared for these types of storms: family plans should be developed, disaster kits should be put in homes, workplaces, schools and cars, and every family member should be taught how to shut off household utilities. Initiating early dismissal from schools and business is an effective mitigation measure and should be encouraged.

Severe weather cannot be prevented, but measures can be taken to mitigate the effects. Critical infrastructure and utilities can be hardened to prevent damage during an event. The secondary effect of flooding can be addressed through decreasing runoff and water velocity. Important issues associated with severe weather in the King County planning area include the following:

- Redundancy of power supply throughout the planning area must be evaluated to better understand what areas may be vulnerable.
- The capacity for backup power generation is limited.
- The County has numerous isolated population centers.
- Public education on dealing with the impacts of severe weather needs to be provided so that citizens can be better informed and prepared for severe weather events.
- Debris management (downed trees, etc.) must be addressed, because debris can impact the severity of severe weather events, requires coordination efforts, and may require additional funding.
- The effects of climate change may result in an increase in frequency of extreme heat events.

CHAPTER 14.

SEVERE WINTER WEATHER

14.1 GENERAL BACKGROUND

Severe winter weather is any dangerous cold-weather phenomena with the potential to cause damage, serious social disruption, or loss of human life. It includes snowstorms, ice storms, blizzards, and extreme cold. Typically, significant winter storms occur during the transition between cold and warm periods.

> **DEFINITIONS**
>
> **Freezing Rain**—The result of rain occurring when the temperature is below the freezing point. The rain freezes on impact, resulting in a layer of ice up to an inch thick. In severe events, an evergreen tree 60 feet high and 30 feet wide can be burdened with up to 6 tons of ice, creating a threat to utility lines and transportation routes.
>
> **Severe Local Storm—** Small-scale atmospheric systems, including ice storms and snowstorms. These storms may cause a great deal of destruction, but their impact is generally confined to a small area. Typical impacts are on transportation infrastructure and utilities.
>
> **Winter Storm—**A storm having significant snowfall, ice, and/or freezing rain; the quantity of precipitation varies by elevation.

14.1.1 Blizzards and Snowstorms

The National Weather Service defines a winter storm as having significant snowfall, ice and/or freezing rain; the quantity of precipitation varies by elevation. Heavy snowfall is 4 inches or more in a 12-hour period, or 6 inches or more in a 24-hour period in non-mountainous areas; and 12 inches or more in a 12-hour period or 18 inches or more in a 24-hour period in mountainous areas. There are three key ingredients to a severe winter storm:

- Cold Air—Below-freezing temperatures in the clouds and near the ground are necessary to make snow and/or ice.
- Moisture—Moisture is required in order to form clouds and precipitation. Air blowing across a body of water, such as a large lake or the ocean, is an excellent source of moisture.
- Lift—Lift is required in order to raise the moist air to form the clouds and cause precipitation. An example of lift is warm air colliding with cold air and being forced to rise over the cold dome. The boundary between the warm and cold air masses is called a front. Another example of lift is air flowing up a mountain side.

Areas most vulnerable to winter storms are those affected by convergence of dry, cold air from the interior of the North American continent and warm, moist air off the Pacific Ocean. When strong storms crossing the Pacific arrive at the coast, if the air is cold enough, snow falls. As the moisture rises into the mountains, heavy snow closes the mountain passes and can cause avalanches. Cold air from the north has to filter through mountain canyons into the basins and valleys to the south. If the cold air is deep enough, it can spill over the mountain ridge. As the air funnels through canyons and over ridges, wind speeds can reach 100 mph. High winds with snow results in a blizzard.

Heavy snow can immobilize a region and paralyze a city, stranding commuters, stopping the flow of supplies, and disrupting emergency and medical services. Accumulations of snow can collapse buildings and knock down trees and power lines. In rural areas, homes and farms may be isolated for days, and

unprotected livestock may be lost. In the mountains, heavy snow can lead to avalanches. The cost of snow removal, repairing damages, and loss of business can have large economic impacts on cities and towns.

14.1.2 Ice Storms

The National Weather Service defines an ice storm as a storm that results in the accumulation of at least 0.25 inches of ice on exposed surfaces. Ice storms occur when rain falls from a warm, moist, layer of atmosphere into a below freezing, drier layer near the ground. The rain freezes on contact with the cold ground and exposed surfaces, causing damage to trees, utility wires, and structures (see Figure 14 -54).

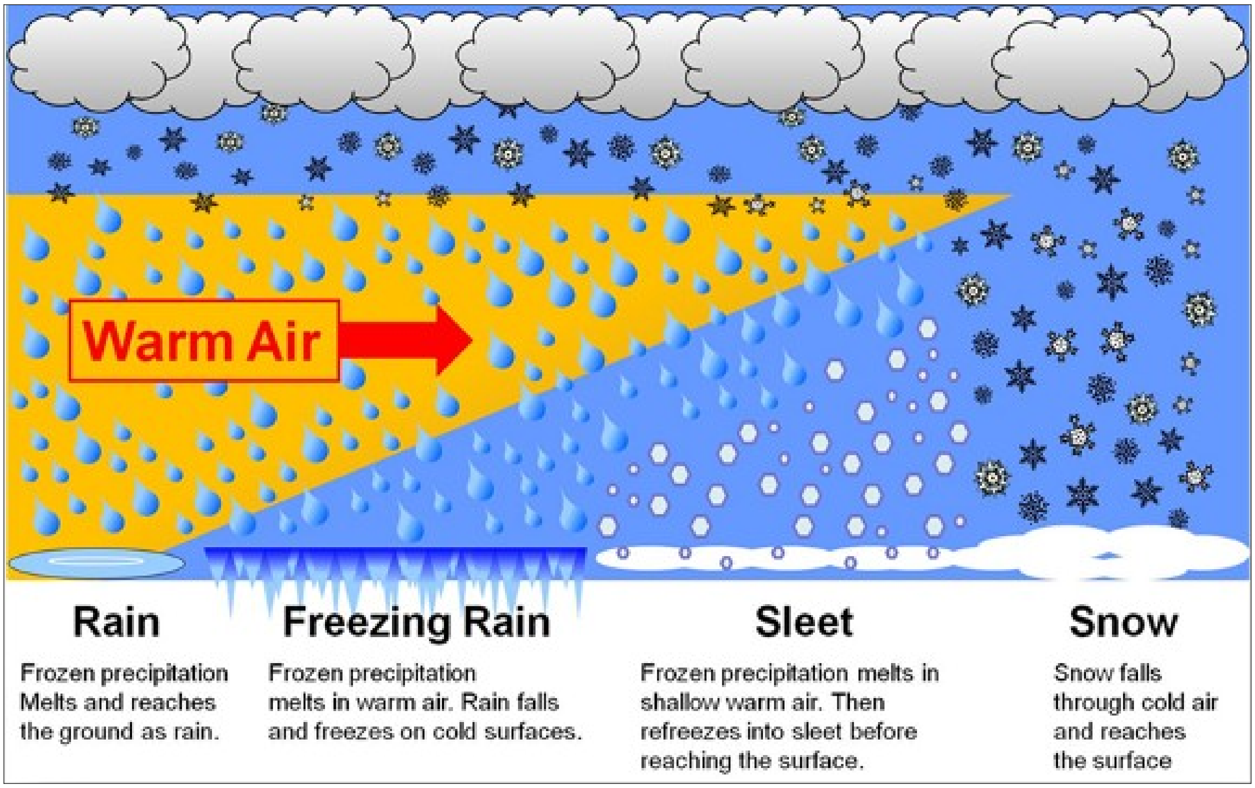


Figure 14-54. The Formation of Different Kinds of Precipitation

Ice accretion generally ranges from a trace to 1 inch. Accumulations between 1/4-inch and 1/2-inch can cause small branch and faulty limb breakage. Accumulations of 1/2-inch to 1 inch can cause significant breakage. Strong winds increase the potential for damage from ice accumulation.

14.1.3 Extreme Cold and Wind Chill

Weather that constitutes extreme cold varies across different parts of the U.S. In regions relatively unaccustomed to winter weather, near freezing temperatures are considered extreme cold (CDC, 2014a). Extreme cold can often accompany severe winter storms. Wind can exacerbate the effects of cold temperatures by carrying heat away from the body more quickly, thus making it feel colder than is indicated by the temperature. This phenomenon is known as wind chill. Wind chill is the temperature that your body feels when the air temperature is combined with wind speed (CDC, 2014a). Figure 14 -55 shows the value of wind chill based on ambient temperature and wind speed.

Temperature (ºF)

Wind (mph)	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
5	36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
10	34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
15	32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
20	30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
25	29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
30	28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
35	28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
40	27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
45	26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
50	26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
55	25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89	-97
60	25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91	-98

Calm

Frostbite Times: 30 minutes, 10 minutes, 5 minutes

$$\text{Wind Chill (ºF)} = 35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16})$$

Where, T= Air Temperature (ºF) V= Wind Speed (mph)

Effective 11/01/01

Figure 14-55. Wind Chill Chart

14.2 HAZARD PROFILE

14.2.1 Past Events

Table 14 -71 lists King County winter weather events since 1960 recorded in the SHELDUS database.

14.2.2 Location

Severe winter weather events have the potential to happen anywhere in the planning area. In general, snowfall increases at higher elevations and farther from Puget Sound. In most of the planning area, snow typically melts within a day or two and rarely exceeds 15 inches (Washington Regional Climate Center, 2014). Figure 6 -12 shows the distribution of average minimum temperatures over the planning area.

14.2.3 Frequency

There is no record indicating the frequency of extreme cold events in King County; however, records from the Seattle-Tacoma International Airport indicate that on average there are 1.6 days per year when the maximum temperature is less than 32ºF and 24.9 days per year when the minimum temperature is below 32ºF (Washington Regional Climate Center, 2014). According to SHELDUS, 44 winter weather events have affected the planning area since 1960. According to the Washington State Hazard Mitigation Plan, the recurrence interval for winter storms in King County is at least every other year (70 percent).

TABLE 14-71.
PAST SEVERE WINTER WEATHER EVENTS IMPACTING PLANNING AREA

Date	Hazard Type/Remarks	Injuries[a]	Fatalities[a]	Property & Crop Damage
11/20/1960	Winter Weather/Snow	0.06	0	$2,941
12/16/1964	Severe Storm, Thunderstorm, Winter Weather/Cold wave, heavy snowfall, heavy rain	0	0.03	$128,205
1/26/1965	Flooding, Landslide, Winter Weather/Flooding, mudslide, snow slide	0	0	$12,821
10/1/1967	Severe Storm, Thunderstorm, Wind, Winter Weather/Wind, rain, snow	0	0	$278
12/30/1968	Winter Weather/Snow	0	0	$1,282
1/14/1971	Wind, Winter Weather/Wind and Snow	0	0.03	$1,282
1/22/1971	Severe Storm, Thunderstorm, Wind, Winter Weather/Wind, Rain and Snow	0.33	4	$2,778
1/24/1972	Winter Weather/Near Blizzard	0	0	$14,103
1/24/1972	Winter Weather/Freeze	0	0	$12,949
12/4/1972	Winter Weather/Cold, Freeze, Snow	0	0	$12,821
12/26/1974	Wind, Winter Weather/Snow & Wind	0	0	$16,683
1/7/1975	Wind, Winter Weather/Wind and Snow	0.05	0	$1,282
11/30/1975	Avalanche, Winter Weather/Snowstorm, Avalanche	0	0	$2,632
12/2/1985	Winter Weather/Ice Storm	0	1	$128
2/1/1989	Winter Weather/Snowstorm/High Wind	0	4.03	$128,205
12/18/1990	Wind, Winter Weather/Snowstorm, High Winds	0	0	$416,667
12/19/1990	Winter Weather/Hard Freeze	0	0	$1,282
12/29/1990	Winter Weather/Hard Freeze	0	0	$1,282
12/8/1992	Winter Weather/Ice	0	4	$714
12/10/1992	Winter Weather/Heavy Snow	0.17	0	$4,167
1/19/1993	Winter Weather/Freezing Rain	0.63	0.67	$12,500
12/24/1993	Winter Weather/Ice	1.7	0	$5,000
2/23/1994	Winter Weather/Heavy Snow	0	0	$417
1/18/1996	Winter Weather/Heavy Snow	2	0.5	$0
11/19/1996	Winter Weather/Heavy Snow	22	0	$0
12/28/1996	Winter Weather/Heavy Snow	0	1	$10,416,667
2/15/2001	Winter Weather/	0	0	$500
11/19/2003	Winter Weather/	0	0	$75,000
1/6/2004	Winter Weather/	0	0	$90,909
12/1/2005	Winter Weather/Heavy Snow	0	0	$1,667
11/26/2006	Winter Weather/Heavy Snow	0	0	$1,083,333
1/10/2007	Winter Weather/Heavy Snow	0	0	$6,111
2/28/2007	Winter Weather/Winter Weather	0	0	$25,000
2/28/2007	Winter Weather/Heavy Snow	0	0	$1,333
6/10/2008	Winter Weather/Winter Weather	0.5	0.25	$0
12/17/2008	Winter Weather/Heavy Snow	0	0	$57,692
12/18/2008	Winter Weather/Heavy Snow	0	0	$200,000
12/20/2008	Winter Weather/Heavy Snow	0	0	$150,000

**TABLE 14-71.
PAST SEVERE WINTER WEATHER EVENTS IMPACTING PLANNING AREA**

Date	Hazard Type/Remarks	Injuries[a]	Fatalities[a]	Property & Crop Damage
12/20/2008	Winter Weather/Heavy Snow	0	0	$113,636
12/21/2008	Winter Weather/Heavy Snow	0.09	0	$550,136
12/24/2008	Winter Weather/Heavy Snow	0	0	$45,000
12/25/2008	Winter Weather/Winter Weather	0	0	$87,500
1/19/2012	Winter Weather/Ice Storm	0	0	$2,000,000
1/19/2012	Winter Weather/Ice Storm	0.33	0.33	$266,667
12/15/2012	Winter Weather/Heavy Snow	0	0	$0

a. Fractional values of injuries and fatalities indicate that data were available for a multi-county area; per-county counts were estimated by dividing the total by the number of counties in the defined area

Source: http://webra.cas.sc.edu/hvriapps/sheldus_web/sheldus_results.aspx

14.2.4 Severity

The most common problems associated with severe winter storms are immobility and loss of utilities. Fatalities are uncommon, but can occur. Roads may become impassable due to downed trees, ice or snow. Power lines may be downed due to ice accumulation, and services such as water or phone may not be able to operate without power. Physical damage to homes and facilities can be caused by wind or accumulation of snow or ice. Even a small accumulation of snow can cause havoc on transportation systems due to a lack of snow clearing equipment and experienced drivers and the hilly terrain.

Ice storms accompanied by high winds can have especially destructive impacts, especially on trees, power lines, and utility services. While sleet and hail can create hazards for motorists when it accumulates, freezing rain can cause the most dangerous conditions within a community. Ice buildup can bring down trees, communication towers and wires, creating hazards for property owners, motorists and pedestrians. Rain can fall on frozen streets, cars, and other sub-freezing surfaces, creating dangerous conditions.

Over the past 30 years western Washington has had an annual average of 11.4 inches of snowfall per year. Typically, the snow season is November through March. Snowfall records in the region are as follows:

- The one day record is 21 inches in January 1950
- The one month record is 57 inches during January 1950
- The winter long record is 67 inches during the winter of 1968—1969.

14.2.5 Warning Time

Meteorologists can often predict the likelihood of a severe winter storm. This can give several days of warning time. However, meteorologists cannot predict the exact time of onset or severity of the storm. Some storms may have only a few hours of warning time. The Seattle Office of the National Weather Service provides public warnings as appropriate to alert government agencies and the public of possible or impending storm, snow and ice events. The watches and warnings are broadcast over NOAA weather radio and are forwarded to the local media for retransmission using the Emergency Alert System.

14.3 SECONDARY HAZARDS

The most significant secondary hazards associated with severe local storms are floods, falling and downed trees, landslides and downed power lines. Rapidly melting snow combined with heavy rain can overwhelm natural and man-made drainage systems, causing overflow and property destruction. Landslides occur when the soil on slopes becomes oversaturated and fails. Pipes located in poorly insulated homes or in homes that have lost power may freeze or break. If a severe ice storm occurs within King County, prolonged power outages over widespread areas are possible.

14.4 EXPOSURE

14.4.1 Population

A lack of data related to severe winter weather damage prevented a detailed analysis for exposure and vulnerability. However, it can be assumed that the entire planning area is exposed to some extent to severe winter weather events. Certain areas are more exposed due to geographic location and local weather patterns. Populations that do not have adequate shelter are more exposed to the impacts of severe winter weather.

14.4.2 Property

According to the King County Assessor, there are 545,846 buildings within the census tracts that define the planning area. Most of these buildings are residential. All of these buildings are considered to be exposed to the severe winter weather hazard, but structures in poor condition or in particularly vulnerable locations (located on hilltops or exposed open areas) may risk the most damage. The frequency and degree of damage will depend on specific locations.

14.4.3 Critical Facilities and Infrastructure

All critical facilities are likely exposed to severe winter weather. Facilities on higher ground may be exposed to damage from falling trees. The most common problems associated with severe winter weather are loss of utilities. Downed power lines can cause blackouts, leaving large areas isolated. Phone, water and sewer systems may not function. Roads may become impassable due to ice or snow.

14.4.4 Environment

The environment is highly exposed to severe winter weather events. Natural habitats such as streams and trees are exposed to the elements and risk damage from snow and ice. Flooding events caused by snowmelt can produce river channel migration or damage riparian habitat. Storm surges can erode beachfront bluffs and redistribute sediment loads.

14.5 VULNERABILITY

14.5.1 Population

Many of the deaths that result from severe winter weather are indirectly related to the actual weather event, including deaths resulting from traffic accidents on icy roads and heart attacks while shoveling snow. Icy road conditions that lead to major traffic accidents can make it is difficult for emergency personnel to travel. This may pose a secondary threat to life if police, fire, and medical personnel cannot respond to calls.

While all residents in the County are vulnerable to severe winter weather, elderly, low income or linguistically isolated populations, people with life-threatening illnesses, and residents living in areas that

are isolated from major roads or without adequate shelter may be especially vulnerable. Power outages can be life threatening to those dependent on electricity for life support. Isolation of these populations is a significant concern. These populations face isolation and exposure during severe winter weather events and could suffer more secondary effects of the hazard. Power outages can also cause life-threatening situations if residents use alternative means to heat their homes without proper ventilation.

14.5.2 Property

All property is vulnerable during severe winter weather events, but properties in poor condition or in particularly vulnerable locations may risk the most damage. Those that are located under or near overhead lines or near large trees may be vulnerable to falling ice or may be damaged in the event of a collapse.

Loss estimations for the severe winter weather hazard are not based on damage functions, because no such damage functions have been generated. Instead, estimates were developed representing 10 percent, 30 percent and 50 percent of the assessed value of exposed structures. This allows emergency managers to select a range of potential economic impact based on an estimate of the percent of damage to the general building stock. Damage in excess of 50 percent is considered to be substantial by most building codes and typically requires total reconstruction of the structure. Table 14 -72 lists the estimates.

14.5.3 Critical Facilities and Infrastructure

Incapacity and loss of roads are the primary transportation failures resulting from severe winter weather, mostly associated with secondary hazards. Snowstorms in higher elevations can significantly impact the transportation system and the availability of public safety services. Of particular concern are roads providing access to isolated areas and to the elderly. Prolonged obstruction of major routes due to snow can disrupt the shipment of goods and other commerce. Large, prolonged winter storms can have negative economic impacts for the entire region. Economists estimate that the closing of Snoqualmie Pass has an economic cost to the state between $500,000 and $750,000 per hour (Washington State Emergency Management Division, 2010).

Downed trees and ice can create serious impacts on power and above-ground communication lines. Freezing of power and communication lines can cause them to break, disrupting electricity and communication. Loss of electricity and phone connection would leave certain populations isolated because residents would be unable to call for assistance. Water systems may also be impacted during severe winter weather events. The most frequent water system problem related to cold weather is a break in cast iron mainlines. Breaks frequently occur during severe freeze events, as well as during extreme cooling periods in October, November and December. Another common problem during severe freeze events is the failure of commercial and residential water lines. Inadequately insulated potable water and fire sprinkler pipes can rupture and cause extensive damage to property.

14.5.4 Environment

The vulnerability of the environment to severe winter weather is the same as the exposure.

14.6 FUTURE TRENDS IN DEVELOPMENT

All future development will be affected by severe winter weather. The ability to withstand impacts lies in sound land use practices and consistent enforcement of codes and regulations for new construction. The planning partners have adopted the International Building Code, which can deal with the impacts of severe winter weather. Land use policies identified in general plans for the planning area address many of the secondary impacts of the severe winter weather hazard. With these tools, the planning partnership is well equipped to deal with future growth and the associated impacts of severe winter weather.

**TABLE 14-72.
LOSS POTENTIAL FOR SEVERE WINTER WEATHER**

		Estimated Loss Potential from Severe Winter Weather		
	Total Assessed Value	10% Damage	30% Damage	50% Damage
Algona	$902,612,000	$90,261,200	$270,783,600	$451,306,000
Auburn	$17,992,313,000	$1,799,231,300	$5,397,693,900	$8,996,156,500
Beaux Arts	$60,778,000	$6,077,800	$18,233,400	$30,389,000
Bellevue	$49,163,714,000	$4,916,371,400	$14,749,114,200	$24,581,857,000
Black Diamond	$600,388,000	$60,038,800	$180,116,400	$300,194,000
Bothell	$5,215,897,000	$521,589,700	$1,564,769,100	$2,607,948,500
Burien	$9,165,566,000	$916,556,600	$2,749,669,800	$4,582,783,000
Carnation	$328,410,000	$32,841,000	$98,523,000	$164,205,000
Clyde Hill	$845,586,000	$84,558,600	$253,675,800	$422,793,000
Covington	$2,849,591,000	$284,959,100	$854,877,300	$1,424,795,500
Des Moines	$5,742,226,000	$574,222,600	$1,722,667,800	$2,871,113,000
Duvall	$1,108,322,000	$110,832,200	$332,496,600	$554,161,000
Enumclaw	$2,667,155,000	$266,715,500	$800,146,500	$1,333,577,500
Federal Way	$19,102,220,000	$1,910,222,000	$5,730,666,000	$9,551,110,000
Hunts Point	$160,100,000	$16,010,000	$48,030,000	$80,050,000
Issaquah	$9,587,897,000	$958,789,700	$2,876,369,100	$4,793,948,500
Kenmore	$4,000,207,000	$400,020,700	$1,200,062,100	$2,000,103,500
Kent	$33,182,020,000	$3,318,202,000	$9,954,606,000	$16,591,010,000
Kirkland	$22,202,262,000	$2,220,226,200	$6,660,678,600	$11,101,131,000
Lake Forest Park	$2,214,717,000	$221,471,700	$664,415,100	$1,107,358,500
Maple Valley	$3,129,530,000	$312,953,000	$938,859,000	$1,564,765,000
Medina	$947,196,000	$94,719,600	$284,158,800	$473,598,000
Mercer Island	$6,598,328,000	$659,832,800	$1,979,498,400	$3,299,164,000
Milton	$140,733,000	$14,073,300	$42,219,900	$70,366,500
Newcastle	$2,266,792,000	$226,679,200	$680,037,600	$1,133,396,000
Normandy Park	$1,306,626,000	$130,662,600	$391,987,800	$653,313,000
North Bend	$1,453,593,000	$145,359,300	$436,077,900	$726,796,500
Pacific	$830,743,000	$83,074,300	$249,222,900	$415,371,500
Redmond	$23,234,414,000	$2,323,441,400	$6,970,324,200	$11,617,207,000
Renton	$25,825,586,000	$2,582,558,600	$7,747,675,800	$12,912,793,000
Sammamish	$9,306,835,000	$930,683,500	$2,792,050,500	$4,653,417,500
SeaTac	$7,572,236,000	$757,223,600	$2,271,670,800	$3,786,118,000
Seattle	$212,337,688,000	$21,233,768,800	$63,701,306,400	$106,168,844,000
Shoreline	$11,169,471,000	$1,116,947,100	$3,350,841,300	$5,584,735,500
Skykomish	$74,730,000	$7,473,000	$22,419,000	$37,365,000
Snoqualmie	$2,297,236,000	$229,723,600	$689,170,800	$1,148,618,000
Tukwila	$11,628,108,000	$1,162,810,800	$3,488,432,400	$5,814,054,000
Woodinville	$4,522,687,000	$452,268,700	$1,356,806,100	$2,261,343,500
Yarrow Point	$300,638,000	$30,063,800	$90,191,400	$150,319,000
Unincorporated	$44,641,548,000	$4,648,154,800	$13,404,464,400	$22,340,774,000
Total	0	0	0	0

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.3.5 for a discussion of data limitations.

14.7 SCENARIO

Winter storms in the planning area are likely to occur between November and April. These storms would be caused by a sufficient amount of cold polar air flowing down from the north caused by a dip in the jet stream, combined with a significant source of moisture from the Pacific Ocean. Such events would have both short-term and long-term effects. Initially, schools and roads would be closed due to power outages caused by high winds and downed tree obstructions. In more rural areas, some subdivisions could experience limited ingress and egress. Economic losses as a result of closed businesses and disrupted transportation systems would be significant.

14.8 ISSUES

Important issues associated with a severe winter weather in the planning area include the following:

- Older building stock in the planning area is built to low code standards or none at all. These structures could be highly vulnerable to severe winter weather effects such as snow loads.
- Redundancy of power supply throughout the planning area must be evaluated to better understand what areas may be vulnerable.
- Urban forest management programs should be evaluated to help reduce impacts from forest-related damages.
- Climate change may increase the frequency and magnitude of winter flooding events, thus exacerbating severe winter weather events.

CHAPTER 15.

TSUNAMI

15.1 GENERAL BACKGROUND

A tsunami consists of a series of high-energy waves that radiate outward like pond ripples from an area where a generating event occurs. The waves arrive at shorelines over an extended period.

Tsunamis are typically classified as local or distant. Locally generated tsunamis have minimal warning times, leaving few options except to run to high ground. They may be accompanied by damage resulting from the triggering earthquake due to ground shaking, surface faulting, liquefaction or landslides. Distant tsunamis may travel for hours before striking a coastline, giving a community a chance to implement evacuation plans.

In the open ocean, a tsunami may be only a few inches or feet high, but it can travel with speeds approaching 600 miles per hour. As a tsunami enters the shoaling waters near a coastline, its speed diminishes, its wavelength decreases, and its height increases greatly. The first wave usually is not the largest. Several larger and more destructive waves often follow the first one. As tsunamis reach the shoreline, they may take the form of a fast-rising tide, a cresting wave, or a bore (a large, turbulent wall-like wave). The bore phenomenon resembles a step-like change in the water level that advances rapidly (from 10 to 60 miles per hour).

> **DEFINITIONS**
>
> **Seiche**—A standing wave in an enclosed or partly enclosed body of water, normally caused by earthquake activity; can affect harbors, bays, lakes, rivers and canals.
>
> **Tsunami—**A series of traveling ocean waves of extremely long wavelength usually caused by displacement of the ocean floor and typically generated by seismic or volcanic activity or by underwater landslides.

The configuration of the coastline, the shape of the ocean floor, and the characteristics of advancing waves play important roles in the destructiveness of the waves. Offshore canyons can focus tsunami wave energy and islands can filter the energy. The orientation of the coastline determines whether the waves strike head-on or are refracted from other parts of the coastline. A wave may be small at one point on a coast and much larger at other points. Bays, sounds, inlets, rivers, streams, offshore canyons, islands, and flood control channels may cause various effects that alter the level of damage. It has been estimated, for example, that a tsunami wave entering a flood control channel could reach a mile or more inland, especially if it enters at high tide.

The first visible indication of an approaching tsunami may be recession of water (draw down) caused by the trough preceding the advancing, large inbound wave crest. Rapid draw down can create strong currents in harbor inlets and channels that can severely damage coastal structures due to erosive scour around piers and pilings. As the water's surface drops, piers can be damaged by boats or ships straining at or breaking their mooring lines. The vessels can overturn or sink due to strong currents, collisions with other objects, or impact with the harbor bottom.

Conversely, the first indication of a tsunami may be a rise in water level. The advancing tsunami may initially resemble a strong surge increasing the sea level like the rising tide, but the tsunami surge rises faster and does not stop at the shoreline. Even if the wave height appears to be small, 3 to 6 feet for example, the strength of the accompanying surge can be deadly. Waist-high surges can cause strong

currents that float cars, small structures, and other debris. Boats and debris are often carried inland by the surge and left stranded when the water recedes.

At some locations, the advancing turbulent wave front will be the most destructive part of the wave. In other situations, the greatest damage will be caused by the outflow of water back to the sea between crests, sweeping all before it and undermining roads, buildings, bulkheads, and other structures. This outflow action can carry enormous amounts of highly damaging debris with it, resulting in further destruction. Ships and boats, unless moved away from shore, may be dashed against breakwaters, wharves, and other craft, or be washed ashore and left grounded after the withdrawal of the seawater.

15.2 HAZARD PROFILE

15.2.1 Past Events

Geological evidence of tsunamis in the Puget Sound has been found at Cultus Bay on Whidbey Island and at West Point in Seattle. Researchers believe these tsunami deposits are evidence of earthquake activity along the Seattle Fault or other shallow crustal Puget Sound faults. There is evidence that an earthquake around 900 A.D. on the Seattle Fault caused an uplift of up to 20 feet in some areas, triggering a tsunami in central Puget Sound (EMD, 2012). The tsunami deposited a sheet of sand across West Point in Seattle. Computer simulations suggest that wave height may have reached 20 feet at the Seattle waterfront. Sand sheets were also deposited as a result of this event on the southern portion of Whidbey Island and along some tributaries of the Snohomish River. There is also evidence of a past event on Possession Beach on Whidbey Island that caused sloughing and a tsunami.

Verbal accounts among the Snohomish Tribe reported by Colin Tweddell in 1953 describe a great landslide-induced wave caused by the collapse of Camano Head at the south end of Camano Island around the 1820s and 1830s. The slide itself is said to have buried a small village, and the resulting tsunami drowned people who were clamming on Hat (Gedney) Island, 2 miles to the south. Bathymetry between Camano Head and Hat Island could have contributed to the size and destructive power of the wave (Koshimura et al., 2001).

Area lakes have experienced seiches in historical times. In 1891, an earthquake near Port Angeles caused an 8-foot seiche in Lake Washington. Additionally, seiches were generated in area lakes after the 1949 Magnitude-7.1 Olympia earthquake and the 1965 Magnitude-6.5 earthquake. The 1964 Magnitude-9.2 Alaska earthquake created seiches on 14 inland bodies of water in Washington, including Lake Union where several pleasure craft, houseboats and floats sustained minor damage. The Magnitude-7.9 Denali earthquake in Alaska in 2002 resulted in water waves that, again, damaged 20 houseboats and water and sewer lines in Seattle’s Lake Union. Sloshing action was reported in other lakes and swimming pools around the area.

15.2.2 Location

Most tsunamis originate in the Pacific Ocean, where tsunami waves triggered by seismic activity can travel at up to 500 miles per hour, striking distant coastal areas in a matter of hours (see Figure 15 -56). Most recorded tsunamis affecting the Pacific Northwest originated in the Gulf of Alaska. There is also geological evidence of significant impacts from tsunamis originating along the Cascadia subduction zone, which extends from Cape Mendocino, California to the Queen Charlotte Islands in British Columbia. Tsunamis affecting Washington may be induced by geologic events of local origin, or earthquakes at a considerable distance, such as in Alaska or South America.

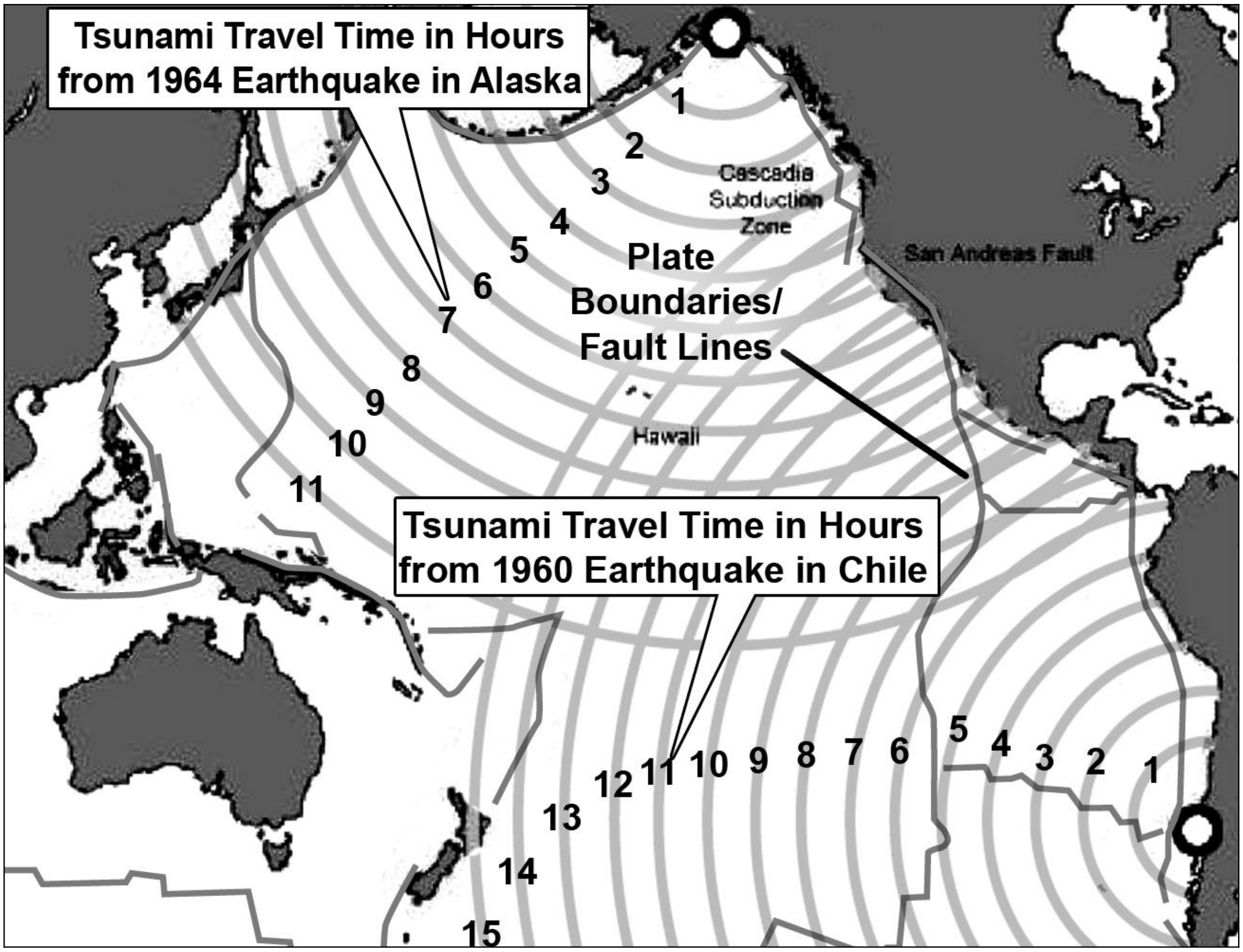


Figure 15-56. Potential Tsunami Travel Times in the Pacific Ocean

Tsunamis generated in the Pacific, including from a Cascadia subduction zone event, would have a difficult time reaching the shores of Puget Sound in King County. The wave would need to pass through the Strait of Juan de Fuca and south into the sound. The complex coastline of Puget Sound would act as a giant baffle and dissipate the wave (Seattle Office of Emergency Management, 2010). For example, The tsunami generated by the Magnitude-9.0 earthquake in Japan in March 2011 did reach Puget Sound, but the maximum wave height recorded was only 0.4 meters. Of greater concern are local tsunamis that may be generated as a result of events in the Puget Sound lowlands. The Washington Department of Natural Resources, working with the National Oceanic and Atmospheric Administration (NOAA) and the National Tsunami Hazard Mitigation Program, is in the process of modeling tsunami impacts in Puget Sound using computer models of earthquake-generated tsunamis from nearby seismic sources.

At the time of the writing of this plan, the only model that has been completed shows the likely tsunami inundation in the Elliott Bay area in Seattle after a Magnitude-7.3 Seattle Fault event (see Figure 15 - 57). This event is considered to be the most dangerous event for King County, based on geological evidence of the tsunami in 900 A.D. This is the only known event resulting from a Seattle Fault earthquake, so the probability of future events is difficult to predict. The Seattle Fault is not the only crustal fault in the area that is thought to be capable of producing tsunamis. Other such faults are present in South Whidbey Island/Mukilteo, Kingston-Edmonds and Tacoma. Future projects of the National Tsunami Hazard Mitigation Program may include mapping additional King County communities that

may be at risk from tsunamis, including Burien, Des Moines, Federal Way, Normandy Park and Vashon Island.

Insert Tsunami Map

Figure 15-57. Tsunami Inundation Area

15.2.3 Frequency

The frequency of tsunamis is related to the frequency of the events that cause them, so it is similar to the frequency of seismic or volcanic activities or landslides. Generally four or five tsunamis occur every year in the Pacific Basin, and those that are most damaging are generated in the Pacific waters off South America rather than in the northern Pacific.

There is only one known occurrence of a tsunami occurring as a result of a Seattle Fault event, although geological evidence suggests that more than one earthquake that could have generated a tsunami has occurred on the fault. Because of this, it is difficult to predict the relative frequency by which such events may occur. Estimates suggest, however, that an event large enough to generate a tsunami may occur once every 1,100 years (King County, 2009). Researchers involved in the Seattle tsunami mapping project believe that a tsunami will accompany a large rupture on the Seattle Fault (Titov et al., 2003).

15.2.4 Severity

Tsunamis are a threat to life and property to anyone living near the ocean. From 1950 to 2007, 478 tsunamis were recorded globally. Fifty-one of these events caused fatalities, to a total of over 308,000 coastal residents. The overwhelming majority of these events occurred in the Pacific basin. Recent tsunamis have struck Nicaragua, Indonesia, and Japan, killing several thousand people. Property damage due to these waves was nearly $1 billion. The March 2011 Japan earthquake and tsunami claimed thousands of lives and caused over $200 billion in damage. Historically, tsunamis originating in the northern Pacific and along the west coast of South America have caused more damage on the west coast of the United States than tsunamis originating in Japan and the Southwest Pacific.

The Cascadia subduction zone will produce the state’s largest tsunami, although it is not likely to significantly impact King County. The Cascadia subduction zone is similar to the Alaska-Aleutian trench that generated the Magnitude-9.2 1964 Alaska earthquake and the Sunda trench in Indonesia that produced the Magnitude-9.3 December 2004 Sumatra earthquake. Native American accounts of past Cascadia earthquakes suggest tsunami wave heights on the order of 60 feet, comparable to water levels in Aceh Province Indonesia during the December 2004 tsunami there. Water heights in Japan produced by the 1700 Cascadia earthquake were over 15 feet, comparable to tsunami heights observed on the African coast after the Sumatra earthquake. The Cascadia subduction zone last ruptured on January 26, 1700, creating a tsunami that left markers in the geologic record from Humboldt County, California, to Vancouver Island in Canada and is noted in written records in Japan. At least seven ruptures of the Cascadia subduction zone have been observed in the geologic record.

15.2.5 Warning Time

Typical signs of a tsunami hazard are earthquakes and/or sudden and unexpected rise or fall in coastal water. The large waves are often preceded by coastal flooding and followed by a quick recession of the water. Tsunamis are difficult to detect in the open ocean; with waves less than 3 feet high. In general, scientists believe it requires an earthquake of at least a magnitude 7 to produce a tsunami.

The Pacific tsunami warning system evolved from a program initiated in 1946. It is a cooperative effort involving 26 countries along with numerous seismic stations, water level stations and information distribution centers. The National Weather Service operates two regional information distribution centers. One is located in Ewa Beach, Hawaii, and the other is in Palmer, Alaska. The Ewa Beach center also serves as an administrative hub for the Pacific warning system.

The warning system only begins to function when a Pacific basin earthquake of magnitude 6.5 or greater triggers an earthquake alarm. When this occurs, the following sequence of actions occurs:

- Data is interpolated to determine epicenter and magnitude of the event.
- If the event is magnitude 7.5 or greater and located at sea, a TSUNAMI WATCH is issued.
- Participating tide stations in the earthquake area are requested to monitor their gages. If unusual tide levels are noted, the tsunami watch is upgraded to a TSUNAMI WARNING.
- Tsunami travel times are calculated, and the warning is transmitted to the disseminating agencies and thus relayed to the public.
- The Ewa Beach center will cancel the watch or warning if reports from the stations indicate that no tsunami was generated or that the tsunami was inconsequential.

This system is not considered to be effective for communities located close to the tsunami because the first wave would arrive before the data were processed and analyzed. In this case, strong ground shaking would provide the first warning of a potential tsunami. Ground shaking is likely to be the only warning available to residents in the planning area.

Seiches are usually earthquake-induced but typically do not occur close to the epicenter of an earthquake, but hundreds of miles away. This is due to the fact that earthquake shock waves close to the epicenter consist of high-frequency vibrations, while those at much greater distances are of lower frequency, which can enhance the rhythmic movement in a body of water. The biggest seiches develop when the period of the ground shaking matches the frequency of oscillation of the water body.

15.3 SECONDARY HAZARDS

Aside from the tremendous hydraulic force of the tsunami waves themselves, floating debris carried by a tsunami can endanger human lives and batter inland structures. Ships moored at piers and in harbors often are swamped and sunk or are left battered and stranded high on the shore. Breakwaters and piers collapse, sometimes because of scouring actions that sweep away their foundation material and sometimes because of the sheer impact of the waves. Railroad yards and oil tanks situated near the waterfront are particularly vulnerable. Oil fires frequently result and are spread by the waves.

Port facilities, naval facilities, fishing fleets and public utilities are often the backbone of the economy of the affected areas, and these are the resources that generally receive the most severe damage. Until debris can be cleared, wharves and piers rebuilt, utilities restored, and fishing fleets reconstituted, communities may find themselves without fuel, food and employment. Wherever water transport is a vital means of supply, disruption of coastal systems caused by tsunamis can have far-reaching economic effects.

15.4 EXPOSURE

The exposure and vulnerability assessments presented in this plan are limited by the available models of tsunami inundation for King County; therefore these assessments are focused solely on the shores of Elliott Bay in Seattle.

15.4.1 Population

The population living in tsunami hazard zones was estimated based on the census blocks that intersect with the estimated tsunami hazard zones. The populations that would be most exposed to this type of hazard are those along beaches, low-lying coastal areas, tidal flats and river deltas that empty into ocean-going waters. Hazus-MH estimated the number of buildings in each block that are in the tsunami hazard zone, and then estimated the total population by multiplying the average King County household size of

2.39 persons per household by the number of structures. Using this approach, it is estimated that exposed population is 4,015 people (less than 1 percent of the county total).

15.4.2 Property

The value of buildings in the tsunami hazard zone within the planning area was generated using Hazus-MH census block information and is summarized in Table 15 -73. The number of buildings in each census block was multiplied by the percentage of that block that lies within the tsunami hazard zone. This methodology estimates that that there are 1,964 structures exposed to the tsunami hazard within the planning area, with an assessed structure and content value of $9,704,665,516. Table 15 -74 shows the general land use of parcels exposed to Tsunami in King County.

TABLE 15-73.
EXPOSURE AND VALUE OF STRUCTURES IN TSUNAMI INUNDATION ZONE (SEATTLE ONLY)

Buildings Exposed	1,964
Value Exposed	
Structure	$4,916,842,434
Contents	$4,787,823,082
Total	$9,704,665,516
% of Total Assessed Value (Seattle)	4.57%

TABLE 15-74.
PRESENT LAND USE IN TSUNAMI INUNDATIONS AREA

Present Use Classification	Area (acres)	% of total (Seattle only)
Agriculture	0	0.0%
Church, Welfare or Religious Service	0	0.0%
Commercial	447	12.5%
Education	0	0.0%
Governmental Services	59	1.7%
Industrial/Manufacturing	404	11.3%
Medical/Dental Services	32	0.9%
Mixed Use Development (Residential & Commercial)	4	0.1%
Mortuary/Cemetery/Crematory	0	0.0%
Nursing Home/Retirement Facility	0	0.0%
Park/Open Space/Golf Course	339	9.5%
Residential	199	5.6%
Terminal or Marina	1,148	32.1%
Utility/Easement/Right of Way	152	4.2%
Water/Tideland/Wetland	39	1.1%
Uncategorized (includes vacant and resource lands)	750	21.0%
Total	**3,573**	**100%**

Source: Summarized from King County parcel data. Acreage covers only mapped parcel extents and thus excludes many rights of way and major water features.

15.4.3 Critical Facilities and Infrastructure

Roads or railroads that are blocked or damaged can prevent access throughout the county and can isolate residents and emergency service providers needing to get to vulnerable populations or to make repairs. Bridges washed out or blocked by tsunami inundation or debris from flood flows also can cause isolation. Water and sewer systems can be flooded or backed up, causing further health problems. Underground utilities can also be damaged during flood events. Table 15 -75 provides an estimate of the number and types of critical facilities exposed to the tsunami hazard.

TABLE 15-75.
CRITICAL FACILITIES AND INFRASTRUCTURE IN TSUNAMI INUNDATION ZONE (SEATTLE)

	Number of Critical Facilities in Inundation Zone
Medical and Health Services	0
Government Function	0
Protective Function	2
Schools	1
Hazmat	26
Other Critical Function	2
Bridges	9
Transportation	51
Water Supply	0
Wastewater	7
Power	1
Communications	2
Total	0

Roads

Roads are an important component in the management of tsunami-related emergencies in that they act is the primary resource for evacuation to higher ground before and during the course of a tsunami event. Roads often act as flood control facilities in low depth, low velocity flood events by acting as levees or berms and diverting or containing flood flows. A GIS analysis indicated that State Route 99 and the West Seattle bridge, as well as numerous arterial roads and streets, may be impacted by tsunami events. This list of roads should not be misinterpreted as possible evacuation routes for tsunami events. Evacuation routes are identified in emergency response plans.

Bridges

Bridges exposed to tsunami events can be extremely vulnerable due to forces transmitted by the wave and by the impact of debris carried by the wave action. A GIS analysis identified nine bridges that would be exposed to the tsunami scenario event.

Water/Sewer/Utilities

Water and sewer systems can be affected by the flooding associated with tsunami events. Floodwaters can back up drainage systems, causing localized flooding. Culverts can be blocked by debris from flood events, also causing localized urban flooding. Floodwaters can get into drinking water supplies, causing contamination. Sewer systems can be backed up. The force of tsunami waves can knock down power lines and radio/cellular communication towers. Power generation facilities can be severely impacted by both the impact of the wave action and the inundation of floodwaters.

15.4.4 Environment

All waterways would be exposed to the effects of a tsunami; inundation of water and introduction of foreign debris could be hazardous to the environment. All wildlife inhabiting the area also is exposed.

15.5 VULNERABILITY

15.5.1 Population

The populations most vulnerable to the tsunami hazard are the elderly, disabled and very young who reside near beaches, low-lying coastal areas, tidal flats and river deltas that empty into ocean-going waters. In the event of a local tsunami generated in or near the planning area, there would be little warning time, so more of the population would be vulnerable. The degree of vulnerability of the population exposed to the tsunami hazard event is affected by the presence and effectiveness of warning systems and whether the public is informed about the system and will evacuate in a timely manner.

For this assessment, the population vulnerable to possible tsunami inundation is considered to be the same as the exposed population.

15.5.2 Property

All structures along beaches, low-lying coastal areas, tidal flats and river deltas would be vulnerable to a tsunami, especially in an event with little or no warning time. The impact of the waves and the scouring associated with debris that may be carried in the water could be damaging to structures in the tsunami’s path. Those that would be most vulnerable are those located in the front line of tsunami impact and those that are structurally unsound. Hazus-MH generated loss estimates for the estimated tsunami hazard areas, as reflected in Table 15 -76. It is estimated that there would be up to $2.081 billion of loss from a scenario tsunami hazard event.

TABLE 15-76.
LOSS ESTIMATES TSUNAMI INUNDATION ZONE (SEATTLE ONLY)

Structures Impacted[a]	905
Estimated Loss from Tsunami	
Structure	$885,031,638
Contents	$1,196,955,771
Total	$2,081,987,409
% of Total Assessed Value (Seattle)	0.98%

a. Impacted structures are those structures expected to receive measurable damage from the scenario tsunami event because they have lowest floor elevations below the projected tsunami inundation height.

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.3.5 for a discussion of data limitations.

15.5.3 Critical Facilities and Infrastructure

Using damage function curves to estimate the percent of damage to critical buildings and their contents, Hazus-MH correlates these estimates to estimated functional down-time. Functional down-time is the time it will take to restore a facility to 100 percent of its functionality. Hazus estimated that on the average, critical facilities would receive 16.7 percent damage to structures and 68 percent damage to contents during the scenario tsunami event. The functional down-time to restore these facilities to 100 percent of their functionality would be approximately 647 days.

15.5.4 Environment

The vulnerability of aquatic habit and associated ecosystems would be highest in low-lying areas close to the coastline. Areas near gas stations, industrial areas and Tier II facilities would be vulnerable due to potential contamination from hazardous materials.

Tsunami waves can carry destructive debris and pollutants that can have devastating impacts on all facets of the environment. Millions of dollars spent on habitat restoration and conservation in the planning area could be wiped out by one significant tsunami. There are currently no tools available to measure these impacts. However, it is conceivable that the potential financial impact of a tsunami event on the environment could equal or exceed the impact on property. Community planners and emergency managers should take this into account when preparing for the tsunami hazard.

15.6 FUTURE TRENDS IN DEVELOPMENT

The Washington State Growth Management Act states that “seismic hazard areas must include areas subject to severe risk of damage as a result of earthquake induced ground shaking, slope failure, settlement or subsidence, soil liquefaction, surface faulting, or tsunamis (WAC 365-190-120).” This interpretation of the Growth Management Act and its effects on future development trends in King County is yet to be determined. The City of Seattle did not designate such areas as geologically hazardous until 2007 after the City’s Environmentally Critical Areas ordinance, which did not designate tsunami inundation zones among other geological hazards as critical areas, was appealed to the Central Puget Sound Growth Management Hearing Board (Central Puget Sound Growth Management Board, 2006). Because all of King County falls within the Board’s jurisdiction, the decision is binding on the entire County. The amended ordinance uses the best available science to acknowledge the suspected risk of tsunami inundation along the marine shoreline and the unknown risk of tsunami inundation along the shores of Lake Washington. Additionally, Lake Union, Lake Washington and Elliot Bay are classified as having known risk of seiche events.

15.7 SCENARIO

The worst-case scenario for the planning area is a local tsunami event triggered by a seismic event within Puget Sound (a Seattle Fault or South Whidbey Island Fault scenario). A seiche would be most likely from a local earthquake in the Puget Sound area. This would probably be very damaging, giving little or no warning time. This could result in great loss of life and property and cause severe environmental impacts.

15.8 ISSUES

The planning team has identified the following issues related to the tsunami hazard for the planning area:

- Hazard Identification: To truly measure and evaluate the probable impacts of tsunamis on planning, new hazard mapping based on probabilistic scenarios likely to occur for King County needs to be created. The science and technology in this field are emerging. For tsunami hazard mitigation programs to be effective, probabilistic tsunami mapping will need to be a key component.
- Present building codes and guidelines do not adequately address the impacts of tsunamis on structures, and current tsunami hazard mapping is not appropriate for code enforcement.
- As tsunami warning technologies evolve, the tsunami warning capability within the planning area will need to be enhanced to provide the highest degree of warning to planning partners with tsunami risk exposure.
- With the possibility of climate change, the issue of sea level rise may become an important consideration as probable tsunami inundation areas are identified through future studies.
- Special attention will need to be focused on the vulnerable communities in the tsunami zone and on hazard mitigation through public education and outreach.

CHAPTER 16.

VOLCANO

16.1 GENERAL BACKGROUND

A volcano is a vent in the earth's crust through which magma, rock fragments, gases, and ash are ejected from the earth's interior. Over time, accumulation of these erupted products on the earth's surface creates a volcanic mountain. There are a wide variety of hazards related to volcanoes and volcanic eruptions. The hazards are distinguished by the different ways in which volcanic materials and other debris flow from the volcano. Molten rock that erupts from the volcano (lava) forms a hill or mountain around the vent. The lava may flow out as a viscous liquid, or it may explode from the vent as solid or liquid particles.

Washington has five major volcanoes in the Cascade Range—Mount Baker, Glacier Peak, Mount Rainier, Mount St. Helens and Mount Adams. Mount Hood, located in northern Oregon, can also affect the state.

Volcanoes can lie dormant for centuries between eruptions, and the risk they pose is not always apparent. When Cascade volcanoes erupt, high-speed avalanches of hot ash and rock called pyroclastic flows, lava flows, and landslides can devastate areas 10 or more miles away, while huge mudflows of volcanic ash and debris called lahars can inundate valleys more than 50 miles downstream. Falling ash from explosive eruptions, called tephra**,** can disrupt human activities hundreds of miles downwind, and drifting clouds of fine ash can cause severe damage to the engines of jet aircraft hundreds or thousands of miles away.

DEFINITIONS

Lahar—A rapidly flowing mixture of water and rock debris that originates from a volcano. While lahars are most commonly associated with eruptions, heavy rains, and debris accumulation, earthquakes may also trigger them.

Lava Flow—The least hazardous threat posed by volcanoes. Cascades volcanoes are normally associated with slow moving andesite or dacite lava.

Stratovolcano—Typically steep-sided, symmetrical cones of large dimension built of alternating layers of lava flows, volcanic ash, cinders, blocks, and bombs, rising as much as 8,000 feet above their bases. The volcanoes in the Cascade Range are all stratovolcanoes.

Tephra—Ash and fragmented rock material ejected by a volcanic explosion

Volcano—A vent in the planetary crust from which magma (molten or hot rock) and gas from the earth's core erupts.

16.1.1 Types of Eruptions

The following types of eruptions occur at volcanoes around the world:

- Hawaiian eruptions, the least violent type of eruption, are characterized by extensive fluid lava flows from central vents or fissures, occasionally accompanied by lava fountains.
- Strombolian eruptions are characterized by moderately fluid lava flows, usually accompanied by a violent lava fountain that produces an abundance of volcanic bombs and cinders.
- Vulcanian eruptions are characterized by viscous magmas that form short, thick flows around vents; very viscous or solid fragments of lava are violently ejected from these vents.
- Pelean eruptions are similar to Vulcanian eruptions but have even more viscous lava; domes form over the vents, and ash flows commonly accompany the dome formations.

- Plinian eruptions, such as that of Mt. St. Helens in 1980, are the most violent eruptions. They include the violent ejection of large volumes of volcanic ash, followed by collapse of the central part of the volcano.

A volcano may exhibit different styles of eruption at different times, and eruptions may change from one type to another as they progress.

16.1.2 Hazards Associated with the Eruption of Volcano

Tephra or Ash Fall

Tephra is fragmented rock material ejected by a volcanic explosion. It normally accompanies the eruptions of volcanoes in the Cascades. These volcanoes tend to erupt lavas so thick and charged with gases that they explode into ash rather than flow.

A 1-inch deep layer of ash weighs an average of 10 pounds per square foot, causing danger of structural collapse. Ash is harsh, acidic, gritty, and smelly. Ash may also carry a high static charge for up to two days after being ejected from a volcano. Although the gases are usually too diluted to constitute danger to a person in normal health, the combination of acidic gas and ash may cause lung problems. Extremely heavy ash can clog breathing passages and cause death. When an ash cloud combines with rain, sulfur dioxide in the cloud combines with water to form diluted sulfuric acid that may cause minor, but painful burns to the skin, eyes, nose, and throat. Hydrochloric acid rains have also been reported. Acid rains may affect water supplies, strip and burn foliage, strip paint, corrode machinery, and dissolve fabric.

Heavy tephra blots out light. Sudden heavy demand for electric light and air conditioning may cause a drain on power supplies, leading to a partial or full power failure. Ash clogs machinery of all kinds and poses a serious threat to aviation because particles can damage aircraft systems and jet engines. It drifts into roadways, railways, and runways where it is slippery and dangerous. Its weight may cause structural collapse. Because winds and air currents easily carry it, it remains a hazard to machinery and transportation (particularly aviation) for months after the eruption.

Lava Flows

Lava flows are coherent masses of hot, partially molten rock that flow downslope; generally following valleys. Lava flows from Cascade volcanoes tend to be short and slow-moving. They may extrude from the main volcanic cone or from nearby cinder cones formed at or near the base of the mountain. The heat of the lava burns vegetation, potentially causing forest or grass fires. Flows may bury roads or other escape routes. Lava flows that move over snow and ice can produce debris flows. Because lava flows are slow moving and take predictable paths, they generally pose little threat to human life, however, they will destroy structures and property in their paths. Additionally, their secondary effects, such as debris flows and wildfires, can threaten life and property.

Volcanic Earthquakes

Volcanic earthquakes, often centered within or beneath a volcano, are usually one of three kinds: pre-eruption earthquakes caused by explosions of steam or underground magma movements, eruption earthquakes caused by explosions and collapse of walls inside the volcano, and post-eruption earthquakes caused by the retreat of magma and interior structural collapse. Although volcanic earthquakes are strong near the volcano, they are generally confined there. There are some exceptions, as with the St. Helens Fault Zone, where a tectonic fault is closely associated with the volcano. Tremors may cause large rock falls, snow avalanches, landslides, and building collapse. Since all Northwest volcanoes are in a regular seismic zone, tremors are monitored by the USGS and the University of Washington Seismology Lab.

Pyroclastic Flows and Surges

Pyroclastic flows and surges can occur during explosive eruptions. Pyroclastic flows are avalanches of hot ash, rock fragments and gas that move at high speeds down the sides of a volcano during explosive eruptions or when the edge of a thick, viscous, lava flow or dome breaks apart or collapses. Such flows can be as hot as 800ºC and are capable of burning and destroying everything in their paths. Pyroclastic surges are more energetic and thus less restricted by topography; they can move over ridge tops. Pyroclastic flows and surges are extremely dangerous. Injury or death can result from a number of factors, including burial, impact, burning and asphyxiation. Although pyroclastic flows move down valleys like lava and debris flows, the immediate hazards associated with them are very different. People can usually outrun the advancing front of a lava flow or climb quickly up the valley sides to a height above a debris flow. The high mobility of pyroclastic flows and surges threaten anyone nearby; even ridge tops and valley slopes may be unsafe.

Lateral Blast

Lateral blasts are explosive events in which energy is directed horizontally instead of vertically from a volcano. They are gas-charged, hot mixtures of rock, gas and ash that are expelled at speeds up to 650 mph. Lateral blasts vary in size, but large ones are fairly rare, with only a few historical examples worldwide. The most recent was the 1980 eruption of Mt. St. Helens when almost everything within the blast zone perished.

16.1.3 Hazards That Can Occur With or Without an Eruption

In addition to the hazards associated with volcanic eruptions (defined as magmatic activity), volcanoes can produce non-magmatic hazards. The USGS differentiates between these two types of volcanic activity because the movement of magma can usually be detected through volcano monitoring, so there is generally some warning prior to a magmatic event. There is generally no movement of magma for non-magmatic events, such as the generation of debris flows, so these events may not be detected before they happen.

Lahar

Lahars are mixtures of water, rock, sand, and mud that rush down valleys leading away from a volcano. They can be hot or cold and form when loose masses of unconsolidated material are saturated, become unstable, and move downslope. The source of water varies but includes rainfall, melting snow or ice, and glacial outburst floods. This danger continues for months, even years following an eruption.

Lahars can travel over 50 miles downstream, commonly reaching speeds between 20 and 40 miles per hour. Sometimes they contain so much rock debris (60 to 90 percent by weight) that they look like fast-moving rivers of wet concrete. Close to the volcano they have the strength to rip huge boulders, trees, and houses from the ground and carry them down-valley. Further downstream they simply entomb everything in mud. The highest speed measured on the slopes of Mt. St. Helens during the 1980 eruption was 88 mph; the lowest, in the lower valleys, was about 2.5 mph. Historically, lahars have been one of the most deadly volcanic hazards.

Volcanic Landslides and Debris Avalanches

Volcanic landslides and debris avalanches of glacial ice or rock debris may be set in motion by explosions, earthquakes, or heat-induced melting of ice and snow. They can occur with or without an accompanying magmatic event. Landslides are defined as the downward and outward movement of slope forming materials, natural rock, snow, glacial ice, soils or any combination of these materials. Debris avalanches are a type of landslide that move at high speeds. Many debris avalanches will, if they contain

sufficient water and fine sediment, transform downstream into debris flows. Therefore the down-valley hazards associated with debris avalanches are the same as those associated with debris flows; the main hazard to life and property being burial and impact.

Explosion of Steam and Other Gases

Explosion of steam and other gases may occur any time hot material comes into contact with water, glacial ice or snow. No eruptive activity is necessary for this to occur. These explosions often contain or are accompanied by one or more of the following: pulverized lava and rock particles in suspension, fragments of older rocks from pea-sized pebbles to hundred-ton boulders, newly erupted hot lava blocks, and a shock wave that may be minimal or may extend for several miles.

Toxic Gases

Pockets or clouds of toxic gases may develop on or near both active and inactive volcanoes. Their chemical poisons can cause internal and external burns, or asphyxiation through oxygen starvation. Carbon dioxide, which causes asphyxiation, is heavier than air and therefore collects in low-lying areas. It is difficult to detect because it is both odorless and colorless. These gases, mixed with ash, make up the eruptive cloud of a volcano.

16.2 HAZARD PROFILE

16.2.1 Past Events

Volcanic eruptions may only occur every few generations. Table 16 -77 and Figure 16 -58 summarize past eruptions in the Cascades and in the Puget Sound region. The last major volcanic eruption in the Northwest was the explosion of Mount St. Helens on May 18, 1980. The eruption reduced the elevation of the mountain from 9,677 feet to 8,364 feet, buried the North Fork of the Toutle River under 23 square miles of volcanic material, and caused 57 human fatalities. Due to its distance, the lava and lahar flow from this eruption did not affect the King County area. The county was exposed to minor tephra fall, which was more of a curiosity than a hazard. Schools and businesses were closed for day or so, but no major disruptions or harm was done.

TABLE 16-77.
PAST ERUPTIONS OF WASHINGTON VOLCANOES

Volcano	Number of Eruptions	Type of Eruptions
Mount Adams	3 in the last 10,000 years, most recent between 1,000 and 2,000 years ago	Andesite lava
Mount Baker	5 eruptions in past 10,000 years; mudflows have been more common (8 in same time period)	Pyroclastic flows, mudflows, ash fall in 1843.
Glacier Peak	8 eruptions in last 13,000 years	Pyroclastic flows and lahars
Mount Rainier	14 eruptions in last 9,000 years; also 4 large mudflows	Pyroclastic flows and lahars
Mount St. Helens	19 eruptions in last 13,000 years	Pyroclastic flows, mudflows, lava, and ash fall

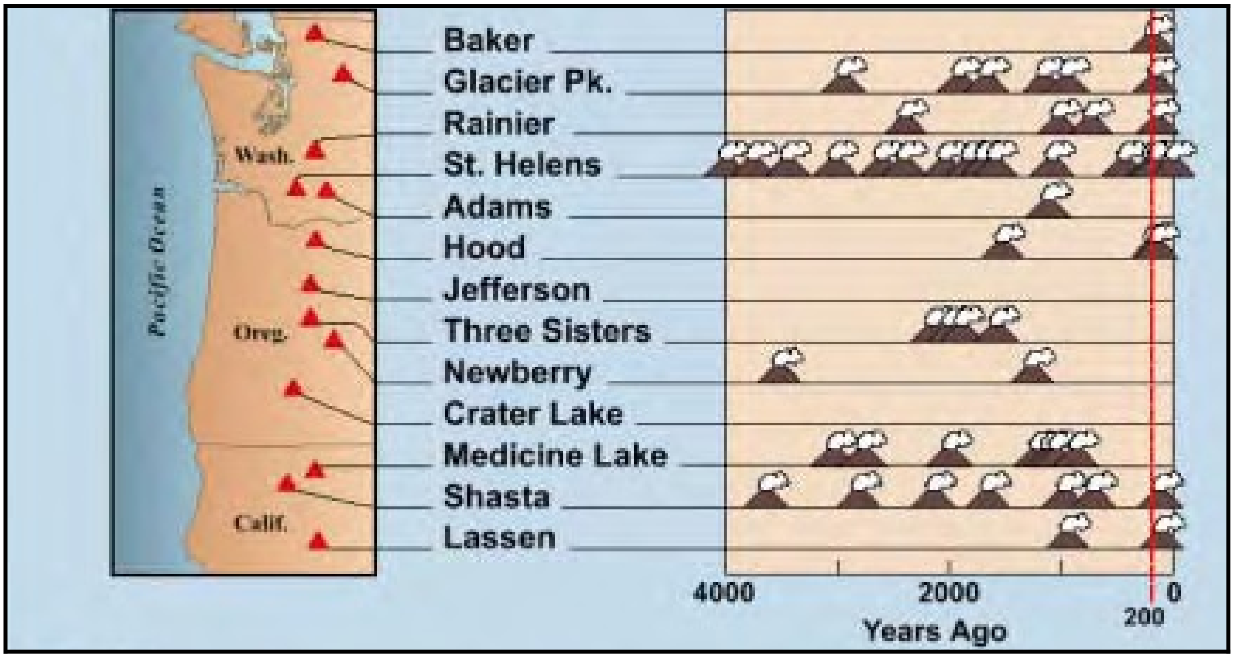


Figure 16-58. Cascade Range Eruptions in the Past 4,000 Years

16.2.2 Location

The Cascade Range extends more than 1,000 miles from southern British Columbia into northern California and includes 13 potentially active volcanic peaks in the U.S. Figure 16 -58 shows the location of the Cascade Mountains in Washington State. The closest volcanoes to King County are Mt. Rainer and Glacier Peak. Other nearby volcanoes include Mt. St. Helens and Mt. Baker. The most hazardous volcanoes are those directly to the west and southwest (along the direction of prevailing winds).

Lahar zones on Mt. Rainer impacting the southern portion of King County have been mapped by USGS. Three lahar scenarios have been mapped, as shown on Figure 16 -59:

- **Case 1, Large Lahars (Recurrence intervals 500 – 1,000 years)—**Areas that could be affected by cohesive lahars that originate as enormous avalanches on weak, chemically altered rock from the volcano. Case 1 lahars can occur with or without eruptive activity. The time interval between such events on Mt. Rainier is about 500 to 1,000 years.
- **Case 2, Moderate Lahars (recurrence intervals 100 – 500 years)—**Areas that could be affected by relatively large, non-cohesive lahars, which are commonly caused by the melting of snow and glacier ice by hot rock fragments during and eruption. They can also have a non-eruptive origin. The time interval between such lahars on Mt. Rainer is near the lower end of the 100- to 500-year range.
- **Post-Lahar Sedimentation**—Areas subject to post-lahar erosion and sedimentation and the ongoing potential for flooding.

Insert Lahar Map

Figure 16-59. Lahar Hazard Areas (Puyallup Valley)

16.2.3 Frequency

The Cascades have experienced an average of one or two eruptions per century during the last 4,000 years. Mount St. Helens is the most active volcano in the Cascades, with four major explosive eruptions in the last 515 years. Still, the probability of an eruption in any given year is extremely low. There is a 1 in 500 probability that portions of two counties in the state will receive 4 inches or more of volcanic ash from any Cascades volcano in any given year, and a 1 in 1,000 probability that parts or all of three or more counties will receive that quantity of ash. There is a 1 in 100 annual probability that small lahars or debris flows will impact river valleys below Mount Baker and Mount Rainier, and less than a 1 in 1,000 annual probability that the largest destructive lahars would flow down Glacier Peak, Mount Adams, Mount Baker or Mount Rainier. Figure 16 -60 shows the annual probability of a tephra accumulation of 4 inches. The probability for King County is 0.02 percent or less in any given year..

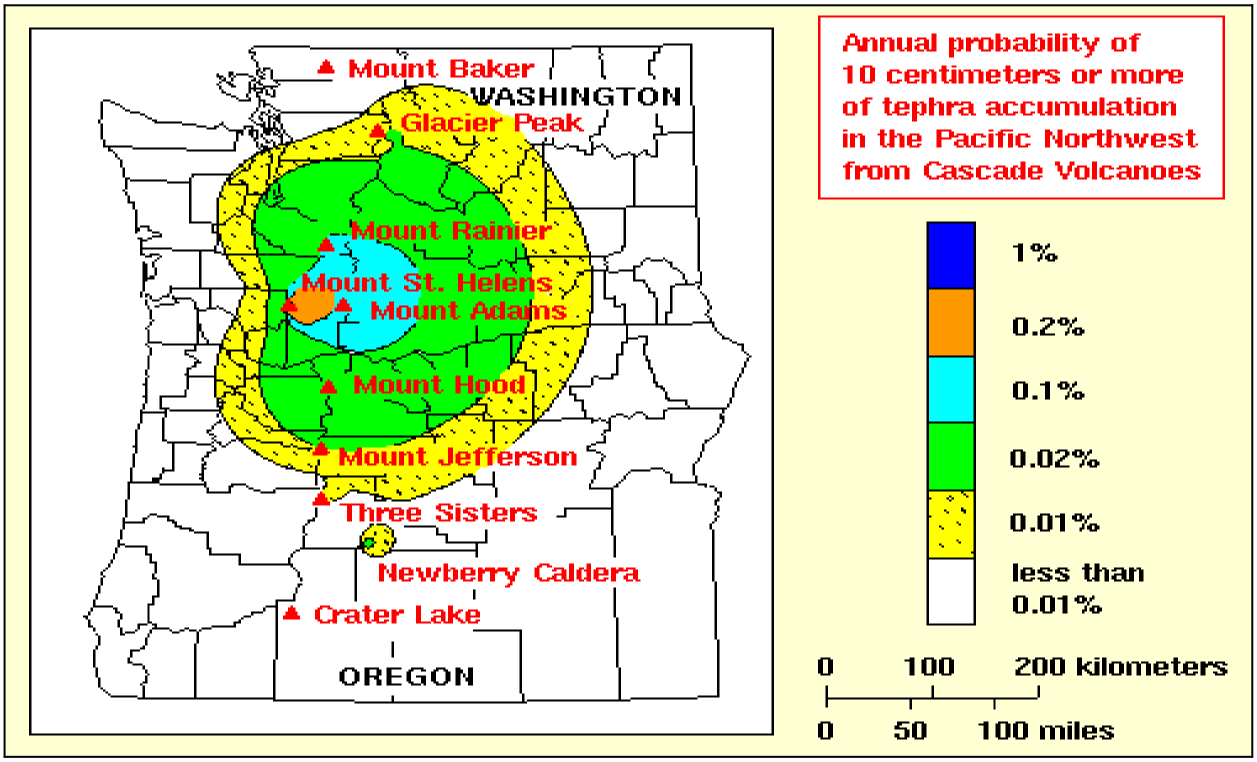


Figure 16-60. Annual Probability of Tephra Fall in the Northwest

16.2.4 Severity

Lahar

The major hazard to human life from debris flows is from burial or impact by boulders and other debris. People and animals also can be severely burned by debris flows carrying hot debris. Buildings and other property in the path of a debris flow can be buried, smashed, or carried away. Because of their relatively high density and viscosity, debris flows can move and even carry away vehicles and other objects as large as bridges and locomotives. Lahars can also erode the sides of river channels, causing bank failures. Buildings, roads, water pipes, or bridge abutments built along those banks may then be incorporated into the debris flow. A large-volume lahar may overtop or destroy a dam. The mudflows that accompanied the Mt. St. Helens eruptions damaged or destroyed more than 200 buildings, ruined 44 bridges, buried 17 miles of railway and more than 125 miles of roadway, badly damaged three logging camps, disabled several community water supply and sewage disposal systems and partly filled channels and reservoirs.

Because debris flows are confined to areas downslope and down-valley from their points of origin, people can avoid them by seeking high ground. People seeking to escape flows should climb valley sides rather than try to outrun debris flows in valley bottoms. Debris-flow hazard decreases gradually down-valley from volcanoes but more abruptly with increasing altitude above valley floors. During eruptive activity or precursors to eruptions, local government officials evacuate areas likely to be affected.

Tephra or Ash Fall

A 1-inch deep layer of ash weighs an average of 10 pounds per square foot, causing danger of structural collapse. Ash is harsh, acidic and gritty, and it has a sulfuric odor. Ash may also carry a high static charge for up to two days after being ejected from a volcano. As ash combines with rain, sulfur dioxide in the ash combines with water to form diluted sulfuric acid that may cause minor, but painful burns to the skin, eyes, nose, and throat.

16.2.5 Warning Time

Monitoring Volcanic Activity at Mount Rainier and Mount St. Helens

The USGS and the Pacific Northwest Seismograph Network at the University of Washington conduct seismic monitoring of all Cascade volcanoes in Washington and Oregon. The USGS began a collaboration with scientists from the Geophysics Program at the University of Washington to monitor seismic activity at both Mount St. Helens and Mount Rainier after the May 1980 eruption at Mount St. Helens. When unusual activity is observed, scientists immediately notify government officials and the public. The U.S. Forest Service serves as the primary dissemination agency for emergency information. As the activity changes, USGS scientists provide updated advisories and meet with local, state and federal officials to discuss the hazards and appropriate levels of emergency response. Experience since 1980 at Mount St. Helens and elsewhere indicates that monitoring is sufficient for scientists to detect the ascent of fresh magma that must take place before another large eruption. This information will enhance warnings and facilitate updated assessments of the hazard.

In addition, the USGS and the National Weather Service monitor lahar and flood hazards at Mount St. Helens. The latter agency has responsibility for providing warnings of floods, including lahars. These monitoring activities not only help nearby communities, but also can provide significant benefit throughout the Pacific Northwest, including King County.

Volcanic Event Notification

An emergency coordination center was established at the U.S. Forest Service office in Vancouver, Washington after the 1980 eruption of Mount St. Helens. A communications network and telephone call-down procedure were developed to facilitate rapid dissemination of information about the activity of the volcano. Information was also disseminated through public meetings, press conferences, and briefings with governmental agencies and private businesses. Emergency coordination and communication is necessary to reduce risk from potential volcanic eruptions in the Cascade region.

Warning Systems

Eruption

The best warning of a volcanic eruption is one that specifies when and where an eruption is likely and what type and size eruption should be expected. Such accurate predictions are sometimes possible but still rare in volcanology. The most accurate warnings are those in which scientists indicate an eruption is probably only hours to days away based on significant changes in a volcano's earthquake activity, ground

deformation, and gas emissions. Experience from around the world has shown that most eruptions are preceded by such changes over a period of days to weeks.

A volcano may begin to show signs of activity several months to a few years before an eruption. However, a warning that specifies months or years in advance when it might erupt are extremely rare. The USGS Cascade Volcano Observatory uses a series of alert levels that correspond generally to increasing levels of volcanic activity. As a volcano becomes increasingly active or as incoming data suggest that a given level of activity is likely to lead to a significant eruption, the Cascade Volcano Observatory declares a correspondingly higher alert level. This alert level ranking offers a framework that the public and civil authorities can use to gauge and coordinate a response to a developing volcano emergency.

Lahar

The USGS, Pierce County Department of Emergency Management and the Washington State Emergency Management Division have established a lahar warning system for the western flank of Mt. Rainier because of the high risk posed to communities below the volcano. Arrays of monitors record ground vibrations of a lahar, computerized evaluation of the data assesses the presence of a flowing lahar. When a lahar is detected, the system issues an automatic alert to emergency-management agencies. Emergency managers can then begin response measures. City, county, and state agencies design and maintain their own notification procedures, evacuation routes, and public-education programs (Driedger and Scott, 2008). This warning systems reduces but does not eliminate risk to people in lahar inundation areas. Individuals in the inundation area need to take immediate action to evacuate in the event of a large lahar event. The USGS estimates that a Case 1 lahar would reach Auburn within 96 minutes after a warning alarm was activated (EMD, 2012).

16.3 SECONDARY HAZARDS

Secondary hazards associated with volcanic eruptions are mud flows and landslides as well as traffic disruptions. The mudflow and landslide hazards are not as typical for most parts of the county, although communities in the south end of the county are located in historical lahar inundation areas. Traffic disruption caused by accumulation of ash fall could affect the entire planning area. It should also be noted that past volcanic activity in the Cascade ranges has been preceded by an earthquake.

16.4 EXPOSURE

All of the King County planning area would be exposed to tephra from volcanic eruptions in the Cascade Range to some degree. The location of the event as well as the prevailing wind direction would influence the extent of this impact. Only the southern portion of the county along the White River is considered to be exposed to lahar flows from Mt. Rainier.

16.4.1 Population

The entire population of King County is exposed to the effects of a tephra fall. Population centers in the lahar path along the White River could become isolated after a volcanic eruption, although there would likely be adequate warning time for evacuation. Population could not be examined by lahar zone because census block groups do not coincide with the lahar risk areas. However, population was estimated using the structure count of buildings within the lahar zones and applying the census value for King County of 2.39 persons per household. Using this approach, it is estimated that the exposed population is 17,920 in the Case 1 lahar zone, 3,527 in the Case 2 lahar zone, and 49,486 in the post-lahar sedimentation zone. Cumulatively, this represents about 3.52 percent of the total population for the planning area.

16.4.2 Property

Lahar

All of the lahar exposure is in the southern portion of the planning area along the White River. All property in the lahar inundation areas would be exposed to lahar flows. The number and value of planning area structures in the three lahar zones are summarized in Table 16 -78 through Table 16 -80. The breakdown of the present land use in the three lahar zones is shown in Table 16 -81 and Table 16 -82.

Tephra

All property in the planning area would be exposed to tephra accumulation in the event of a volcanic eruption.

TABLE 16-78.
EXPOSURE AND VALUE OF STRUCTURES IN CASE 1 LAHAR INUNDATION ZONE

Jurisdiction	Buildings Exposed	Value Exposed			% of Total Assessed Value
		Structure	Contents	**Total**	
Algona	1,116	$474,135,845	$408,162,897	$882,298,743	97.75
Auburn	3,708	$1,936,256,506	$1,696,974,752	$3,633,231,258	19.66
Federal Way	74	$14,231,981	$10,029,017	$24,260,998	0.13
Milton	256	$36,487,773	$18,229,710	$54,717,483	9.72
Pacific	2,073	$540,777,225	$324,967,156	$865,744,381	95.54
Unincorporated	271	$55,528,363	$40,760,327	**$96,288,690**	0.22
Total	0	0	0	0	**0.99**

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.3.5 for a discussion of data limitations.

TABLE 16-79.
EXPOSURE AND VALUE OF STRUCTURES IN CASE 2 LAHAR INUNDATION ZONE

Jurisdiction	Buildings Exposed	Value Exposed			% of Total Assessed Value
		Structure	Contents	**Total**	
Algona	261	$38,851,867	$23,146,394	$61,998,261	6.87
Pacific	1,127	$287,102,157	$181,253,917	$468,356,074	51.68
Unincorporated	8	$1,884,205	$1,462,398	**$3,346,603**	0.01
Total	0	0	0	0	**0.10**

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.3.5 for a discussion of data limitations.

**TABLE 16-80.
EXPOSURE AND VALUE OF STRUCTURES IN POST-LAHAR SEDIMENTATION ZONE**

Jurisdiction	Buildings Exposed	Value Exposed: Structure	Value Exposed: Contents	Value Exposed: **Total**	% of Total Assessed Value
Algona	1	$8,895	$4,448	$13,343	0.00
Auburn	8,283	$4,898,419,869	$4,244,306,287	$9,142,726,156	50.81
Kent	6,466	$9,394,517,677	$8,687,789,310	$18,082,306,986	54.49
Renton	681	$2,382,266,163	$2,577,625,412	$4,959,891,575	19.21%
Seattle	3,421	$3,618,450,762	$3,974,253,224	$7,592,703,987	3.58%
Tukwila	1,467	$3,035,596,239	$3,197,653,732	$6,233,249,971	53.61%
Unincorporated	387	$170,905,971	$161,657,007	**$332,362,978**	0.74
Total	0	0	0	0	**0.97**

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.3.5 for a discussion of data limitations.

**TABLE 16-81.
PRESENT LAND USE IN CASE 1 LAHAR INUNDATION AREA**

Present Use Classification	Case 1 Lahar: Area (acres)	Case 1 Lahar: % of total	Case 2 Lahar: Area (acres)	Case 2 Lahar: % of total
Agriculture	3	0.1%	68	0.4%
Church, Welfare or Religious Service	2	0.1%	125	0.8%
Commercial	251	7.5%	1,105	6.7%
Education	9	0.3%	105	0.6%
Governmental Services	3	0.1%	16	0.1%
Industrial/Manufacturing	79	2.4%	437	2.7%
Medical/Dental Services	3	0.1%	3	0.0%
Mixed Use Development (Residential & Commercial)	1	0.0%	1	0.0%
Mortuary/Cemetery/Crematory	0	0.0%	74	0.4%
Nursing Home/Retirement Facility	1	0.0%	5	0.0%
Park/Open Space/Golf Course	274	8.2%	629	3.8%
Residential	412	12.4%	2,850	17.4%
Terminal or Marina	0	0.0%	70	0.4%
Utility/Easement/Right of Way	38	1.2%	178	1.1%
Water/Tideland/Wetland	0	0.0%	7	0.0%
Uncategorized (includes vacant and resource lands)	2,250	67.7%	10,742	65.5%
Total	**3,324**	**100%**	**16,411**	**100%**

Source: Summarized from King, Pierce and Snohomish County parcel data. Acreage covers only mapped parcel extents and thus excludes many rights of way and major water features.

TABLE 16-82.
PRESENT LAND USE IN POST LAHAR SEDIMENTATION AREAS

Present Use Classification	Area (acres)	% of total
Agriculture	109	0.5%
Church, Welfare or Religious Service	48	0.2%
Commercial	6,813	30.6%
Education	126	0.6%
Governmental Services	131	0.6%
Industrial/Manufacturing	2,026	9.1%
Medical/Dental Services	43	0.2%
Mixed Use Development (Residential & Commercial)	11	0.0%
Mortuary/Cemetery/Crematory	47	0.2%
Nursing Home/Retirement Facility	21	0.1%
Park/Open Space/Golf Course	913	4.1%
Residential	3,422	15.4%
Terminal or Marina	1,733	7.8%
Utility/Easement/Right of Way	1,194	5.4%
Water/Tideland/Wetland	98	0.4%
Uncategorized (includes vacant and resource lands)	5,503	24.7%
Total	**22,238**	**100%**

Source: Summarized from King, Pierce and Snohomish County parcel data. Acreage covers only mapped parcel extents and thus excludes many rights of way and major water features.

16.4.3 Critical Facilities and Infrastructure

Lahar

All critical facilities along the White River are exposed to the lahar hazard. The exposed critical facilities and infrastructure in the three lahar zones within the planning area are summarized in Table 16 -83 through Table 16 -88.

Tephra

All transportation routes are exposed to tephra accumulation, which could create hazardous driving conditions on roads and highways and hinder evacuations and response.

16.4.4 Environment

The environment is highly exposed to the effects of a volcanic eruption. Even if ash fall from a volcanic eruption were to fall elsewhere, it could still be spread throughout the county by surrounding rivers and

streams. A volcanic blast would expose the local environment to effects such as lower air quality and other elements that could harm local vegetation and water quality.

TABLE 16-83.
CRITICAL FACILITIES IN THE CASE 1 LAHAR INUNDATION ZONE

	Medical & Health Services	Government Function	Protective Function	Schools	Hazardous Materials	Other Critical Function	**Total**
Algona	0	0	1	1	0	0	**2**
Auburn	0	0	1	7	10	2	**20**
Milton	0	0	1	0	0	0	**1**
Pacific	0	0	2	1	0	0	**3**
Unincorporated	0	0	0	0	0	0	**0**
Total	**0**	**0**	**5**	**9**	**10**	**2**	**26**

TABLE 16-84.
CRITICAL FACILITIES IN THE CASE 2 LAHAR INUNDATION ZONE

	Medical & Health Services	Government Function	Protective Function	Schools	Hazardous Materials	Other Critical Function	**Total**
Algona	0	0	0	0	0	0	**0**
Auburn	0	0	0	0	0	0	**0**
Milton	0	0	0	0	0	0	**0**
Pacific	0	0	0	1	0	0	**1**
Unincorporated	0	0	0	0	0	0	**0**
Total	**0**	**0**	**0**	**1**	**0**	**0**	**1**

TABLE 16-85.
CRITICAL FACILITIES IN THE POST LAHAR SEDIMENTATION ZONE

	Medical & Health Services	Government Function	Protective Function	Schools	Hazardous Materials	Other Critical Function	Total
Auburn	10	1	3	12	3	20	**49**
Kent	23	0	7	4	20	7	**61**
Renton	5	0	1	1	7	5	**19**
Seattle	4	0	5	0	40	1	**50**
Tukwila	5	0	4	0	7	4	**20**
Unincorporated	0	0	0	0	0	1	**1**

Total	**47**	**1**	**20**	**17**	**77**	**38**	**200**

TABLE 16-86.
CRITICAL INFRASTRUCTURE IN THE CASE 1 LAHAR INUNDATION ZONE

	Bridges	Transportation	Water Supply	Wastewater	Power	Communications	Dams	**Total**
Algona	1	0		0	1	0	1	**3**
Auburn	1	0	0	4	0	0	2	**7**
Milton	3	0	0	0	0	0	0	**3**
Pacific	4	0	0	1	0	0	0	**5**
Unincorporated	2	0	0	0	0	0	0	**2**
Total	**11**	**0**	**0**	**5**	**1**	**0**	**3**	**20**

TABLE 16-87.
CRITICAL INFRASTRUCTURE IN THE CASE 2 LAHAR INUNDATION ZONE

	Bridges	Transportation	Water Supply	Wastewater	Power	Communications	Dams	**Total**
Algona	0	0	0	0	0	0	0	**0**
Auburn	0	0	0	0	0	0	0	**0**
Milton	3	0	0	0	0	0	0	**3**
Pacific	2	0	0	0	0	0	0	**2**
Unincorporated	0	0	0	0	0	0	0	**0**
Total	**5**	**0**	**0**	**0**	**0**	**0**	**0**	**5**

TABLE 16-88.
CRITICAL INFRASTRUCTURE IN THE POST LAHAR SEDIMENTATION ZONE

	Bridges	Transportation	Water Supply	Wastewater	Power	Communications	Dams	**Total**
Auburn	17	3	1	16	0	1	0	**38**
Kent	27	5	0	0	2	0	0	**34**
Renton	14	0	0	1	0	0	0	**15**
Seattle	10	74	0	3	1	2	0	**90**
Tukwila	12	3	1	8	0	1	0	**25**
Unincorporated	4	1	0	1	0	0	0	**6**
Total	**84**	**86**	**2**	**29**	**3**	**4**	**0**	**208**

Lahars racing down river valleys and spreading across floodplains tens of miles downstream from a volcano often cause serious economic and environmental damage. A lahar's turbulent flow front and the boulders and logs carried by the lahar can easily crush, abrade, or shear off at ground level just about anything in the path of the lahar. Even if not crushed or carried away by the force of a lahar, buildings and valuable land may become partially or completely buried by one or more cement-like layers of rock debris. By destroying bridges and key roads, lahars can trap people in areas vulnerable to other hazardous volcanic activity, especially if the lahars leave deposits that are too deep, too soft, or too hot to cross. Lahars can destroy by direct impact, lead to increased deposition of sediment, block tributary streams and bury valleys and communities with debris.

16.5 VULNERABILITY

16.5.1 Population

Lahar

Since there is generally adequate warning time before a volcanic event, the population vulnerable to the lahar hazard consists of those who choose not to evacuate or are unable to evacuate. The latter includes the elderly and the very young.

Tephra

The entire population of the planning area is vulnerable to the damaging effects of volcanic ash fall in the event of a volcanic eruption. The elderly, very young and those who experience ear, nose and throat problems are especially vulnerable to the tephra hazard.

16.5.2 Property

Lahar

There are currently no generally accepted damage functions for volcanic hazards in risk assessment platforms such as Hazus-MH. Therefore the planning team was not able to generate damage estimates for this hazard. All properties listed in Table 16 -78 through Table 16 -80 are vulnerable to the lahar hazard in the planning area. These lahar inundation areas are the outflow areas of past volcanic eruptions and are potential outflow areas for future volcanic eruptions. The most vulnerable structures would be those that are located closest to the lahar outflow areas, and those that are not structurally sound.

Tephra

All of the property exposed to nature in the planning area is exposed to the effects of a tephra fall. Among these properties, the most vulnerable structures are those that are not as structurally sound and may collapse under the excessive weight of tephra and possible rainfall. Vulnerable property includes equipment and machinery left out in the open, such as combines, whose parts can become clogged by the fine dust. Infrastructure, such as drainage systems, is potentially vulnerable to the effects of a tephra fall, since the fine ash can clog pipes and culverts. This may be more of a problem if an eruption occurs during winter or early spring when precipitation is highest and floods are most likely.

To estimate the loss potential for this hazard, a qualitative approach was used, based on recommendations from FEMA guidelines on state and local mitigation planning. Loss estimation tools such as Hazus-MH currently do not have the ability to analyze impacts from volcano hazards. For this study, it was decided

to use 0.1 percent as the loss ratio for the volcano hazard. Assessed valuations for the entire planning area were the basis for these estimations. The results are summarized in Table 16 -89.

TABLE 16-89.
LOSS ESTIMATES FOR TEPHRA

Jurisdiction	Exposed Value	Estimated Loss Potential @ 0.1% Damage
Algona	$902,612,000	$902,612
Auburn	$17,992,313,000	$17,992,313
Beaux Arts	$60,778,000	$60,778
Bellevue	$49,163,714,000	$49,163,714
Black Diamond	$600,388,000	$600,388
Bothell	$5,215,897,000	$5,215,897
Burien	$9,165,566,000	$9,165,566
Carnation	$328,410,000	$328,410
Clyde Hill	$845,586,000	$845,586
Covington	$2,849,591,000	$2,849,591
Des Moines	$5,742,226,000	$5,742,226
Duvall	$1,108,322,000	$1,108,322
Enumclaw	$2,667,155,000	$2,667,155
Federal Way	$19,102,220,000	$19,102,220
Hunts Point	$160,100,000	$160,100
Issaquah	$9,587,897,000	$9,587,897
Kenmore	$4,000,207,000	$4,000,207
Kent	$33,182,020,000	$33,182,020
Kirkland	$22,202,262,000	$22,202,262
Lake Forest Park	$2,214,717,000	$2,214,717
Maple Valley	$3,129,530,000	$3,129,530
Medina	$947,196,000	$947,196
Mercer Island	$6,598,328,000	$6,598,328
Milton	$140,733,000	$140,733
Newcastle	$2,266,792,000	$2,266,792
Normandy Park	$1,306,626,000	$1,306,626
North Bend	$1,453,593,000	$1,453,593
Pacific	$830,743,000	$830,743
Redmond	$23,234,414,000	$23,234,414
Renton	$25,825,586,000	$25,825,586
Sammamish	$9,306,835,000	$9,306,835
SeaTac	$7,572,236,000	$7,572,236
Seattle	$212,337,688,000	$212,337,688
Shoreline	$11,169,471,000	$11,169,471
Skykomish	$74,730,000	$74,730
Snoqualmie	$2,297,236,000	$2,297,236
Tukwila	$11,628,108,000	$11,628,108
Woodinville	$4,522,687,000	$4,522,687
Yarrow Point	$300,638,000	$300,638
Unincorporated	$44,681,548,000	$556,716,699
Total	0	0

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.3.5 for a discussion of data limitations.

16.5.3 Critical Facilities and Infrastructure

Lahar

Transportation routes that intersect with the lahar inundation zone are most vulnerable, especially depending on their structural stability. This would include roads, bridges and the BNSF Railway. The most vulnerable spots are those that directly intersect with a lahar outflow area and are not structurally sound. Utilities are vulnerable to damage from lahars due to the debris that may be carried. Most vulnerable are those that are located on or near parcels that intersect with the lahar outflow area or those that receive input from area streams and rivers that lahar flow through. Water treatment plants and wastewater treatment plants are vulnerable to contamination from debris that may be carried by a lahar. Electrical transmission lines that provide a portion of the electrical power to the Seattle-Tacoma metropolitan area may be severed during an eruption.

Tephra or Ash Fall

Ash fall accumulation of less than one-half inch is capable of creating temporary disruptions of transportation operations and sewage disposal and water treatment systems. Highways and roads could be closed for hours, days, or weeks afterwards. The series of eruptions at Mount St. Helens in 1980 caused Interstate 90 from Seattle to Spokane to close for a week. The impact of the ash fall caused the Seattle and Portland International Airports to close for a few days.

The gritty ash can cause substantial problems for internal-combustion engines and other mechanical and electrical equipment. The ash can contaminate oil systems, clog air filters, and scratch moving surfaces. Fine ash can also cause short circuits in electrical transformers, which in tum cause power blackouts.

16.5.4 Environment

The environment is very vulnerable to the effects of a volcanic eruption. A lahar could be very damaging to area rivers and streams and could redirect water flow and cause changes in water courses. Ash fall would expose the local environment to lower air quality and other effects that could harm vegetation and water quality. The sulfuric acid contained in volcanic ash could be very damaging to area vegetation, waters, wildlife and air quality. Rivers and streams are also vulnerable to damage due to ash fall.

16.6 FUTURE TRENDS IN DEVELOPMENT

Lahar

Development in lahar inundation areas is not currently held to more restrictive standards than typically adopted building codes and land use regulations. These areas have been densely settled. Population within King County, including areas susceptible to lahar inundation, continues to grow, so development of these areas is expected to continue.

Tephra or Ash Fall

All future development in the planning area will be susceptible to the potential impacts from volcanic eruptions causing ash fall within the region. While this potential impact on the built environment is not considered to be significant, the economic impact on industries that rely on machinery and equipment such as agriculture or civil engineering projects could be significant. Since the extent and location of this hazard is difficult to gauge because it is dependent upon many variables, the ability to institute land use

recommendations based on potential impacts of this hazard is limited. While the impacts of tephra are sufficient to warrant risk assessment for emergency management purposes, they are not sufficient to dictate land use decisions.

16.7 SCENARIO

The worst case scenario for King County would be a massive eruption from Mt. Rainier. The lahar flow along the White River in conjunction with this eruption could have devastating impacts on facilities in the White River basin, similar to those seen along the Toutle River following the Mt. St. Helens eruption in 1980. King County resources would be taxed during such an event with widespread damage in the south portion of the county. Most loss of life is likely to be avoided as a result of adequate warnings.

16.8 ISSUES

Volcanic activity at Mt. Rainier is believed to pose the greatest threat to King County and its residents. Because of the inactivity of Mt. Rainier, people have settled on its slopes and along the paths taken by lahar and mudflow drainage. If Mt. Rainier becomes active and erupts or has large lahars or mudflows, all human life and property located on its slopes and along its drainage systems (rivers) are potentially vulnerable.

Explosive eruptions at Glacier Peak or Mt. St. Helens would produce ash that would pose health concerns for residents, damage property, and cause major problems for transportation, local industry, communication and utilities. Non-magmatic events at other active Cascade volcanoes would not directly impact King County. However, County residents could be vulnerable if visiting a volcano during volcanic activity.

Volcanic eruptions can disrupt the normal flow of commerce and daily human activity without causing severe physical harm or damage. Ash that is a few inches thick can halt traffic, cause rapid wear of machinery, clog air filters, block drains, creeks, and water intakes, and impact agriculture. Removal and disposal of large volumes of deposited ash can also have significant impacts on government and business. The interconnectedness of the region’s economy can be disturbed after a volcanic eruption. Roads, railroads, and bridges can be damaged from lahars and mudflows. The Mount St. Helens May 1980 eruption demonstrated the negative effect on the tourism industry. Conventions, meetings, and social gatherings were canceled or postponed in cities and resorts throughout Washington and Oregon in areas not initially affected by the eruption. However, the eruption did lead to the creation of a thriving tourist industry for decades following the event.

Transportation of goods may also be halted. Subsequent airport closures can disrupt airline schedules for travelers. In addition, the movement of goods via major highways can also be halted due to debris and tephra in the air. The Mount St. Helens event in May 1980 cost trade and commerce an estimated $50 million in only two days, as ships were unable to navigate the Columbia River. Clouds of ash often cause electrical storms that start fires, and damp ash can short-circuit electrical systems and disrupt radio communication. Volcanic activity can also lead to the closure of nearby recreation areas as a safety precaution long before the activity ever culminates into an eruption.

Researchers continue to develop methods to predict volcanic eruptions accurately. Indications that an eruption may be imminent include swarms of small earthquakes as the magma rises up through the volcano, increases in sulfur dioxide emissions, and physical swelling of mountain slopes. The USGS is currently experimenting with a variety of sensors on Mt. Rainier in order to attempt predictions. While these methods have not been perfected, scientists were able to predict the eruptions of Mt. Pinatubo in the Philippines and Mt. Unzen in Japan.

Since volcanic episodes have been fairly predictable in the recent past, there is not as much concern about loss of life, but there is concern with loss of property, infrastructure and severe environmental impacts.

CHAPTER 17.

FIRE

17.1 GENERAL BACKGROUND

King County experiences three types of fire threats: structure fires, wildfires and wildland urban interface (WUI) fires where development is adjacent to densely vegetated areas.

17.1.1 Structure Fires

Structure fires are not typically considered an emergency, except when the fire can spread to adjoining structures.

Often, older structures do not conform to modern building and fire codes and do not contain fire detection devices. These structures are also prone to faulty electrical, heating and other utility systems due to age and lack of proper maintenance. Many of these older structures were constructed very close together, enabling fire to spread rapidly from one to another. Older apartment buildings and hotels also face increased risk of rapid fire spread due to inadequate firewall protection and the lack of fire detection and sprinkler systems.

Some newer residential structures are not as vulnerable to fire as older structures. These structures include fire resistive features that conform to modern fire and building codes, as well as fire detection or extinguishing systems. The likelihood of a major fire spreading from these structures to adjoining structures or units before it can be brought under control is significantly reduced.

The storage and use of hazardous materials by commercial and industrial occupancies not only increases the risk of fire but also poses a threat to firefighters and the community if they should become involved in a fire.

Structure fires are a potential secondary hazard of earthquakes. One study estimated that 80 to 100 fires would occur from a large earthquake in the Seattle area.

17.1.2 Wildfires

A wildfire is any uncontrolled fire on undeveloped land that requires fire suppression. Wildfires can be ignited by lightning or by human activity such as smoking, campfires, equipment use, and arson. Controlled burns are not considered hazards unless they escape control.

DEFINITIONS

Conflagration—A fire that grows beyond its original source area to engulf adjoining regions. Wind, extremely dry or hazardous weather conditions, excessive fuel buildup and explosions are usually the elements behind a wildfire conflagration.

Firestorm—A fire that expands to cover a large area, often more than a square mile. A firestorm usually occurs when many individual fires grow together into one. The involved area becomes so hot that all combustible materials ignite, even if they are not exposed to direct flame. Temperatures may exceed 1000°C. Superheated air and gases of combustion rise over the fire zone, drawing surface winds in from all sides, at velocities up to 50 miles per hour. Although firestorms seldom spread because of the inward direction of the winds, once started there is no known way of stopping them. Within the area of the fire, lethal concentrations of carbon monoxide are present; combined with the intense heat, this poses a serious life threat to responding fire forces. In very large events, the rising column of heated air and combustion gases carries enough soot and particulate matter into the upper atmosphere to cause cloud nucleation, creating a locally intense thunderstorm and the hazard of lightning strikes.

Interface Area—An area susceptible to wildfires and where wildland vegetation and urban or suburban development occur together. An example would be smaller urban areas and dispersed rural housing in forested areas.

Wildfire—Fires that result in uncontrolled destruction of forests, brush, field crops, grasslands, and real and personal property in non-urban areas. Because of their distance from firefighting resources, they can be difficult to contain and can cause a great deal of destruction.

Fire hazards present a considerable risk to vegetation and wildlife habitat. Short-term loss caused by a wildfire can include the destruction of timber, wildlife habitat, scenic vistas, and watersheds. Long-term effects include smaller timber harvests, reduced access to affected recreational areas, and destruction of cultural and economic resources and community infrastructure. Vulnerability to flooding increases due to the destruction of watersheds. An average of 905 wildfires burn 6,488 acres annually in Washington State, with a resource loss of $2,103,884.

The probability of a wildfire in any one locality on a particular day depends on fuel conditions, topography and weather conditions, as described in the following sections.

Fuels

Fuels are classified by weight or volume (fuel loading) and by type, including living and dead vegetation on the ground, brush and small trees on the surface, and tree canopies above the ground. Fuel loading, often expressed in tons per acre, can be used to describe the amount of vegetative material available. If fuel loading doubles, the energy released also can be expected to double. Each fuel type is given a burn index, which is an estimate of the amount of potential energy that may be released, the effort required to contain a fire in a given fuel, and the expected flame length. Different fuels have different burn qualities. Some fuels burn more easily or release more energy than others. Lighter fuels such as grasses, leaves and needles quickly expel moisture and burn rapidly, while heavier fuels such as tree branches, logs and trunks take longer to warm and ignite.

Continuity of fuels is expressed in terms of horizontal and vertical dimensions. Horizontal continuity represents the distribution of fuels over the landscape. Vertical continuity links fuels at the ground surface with tree crowns. Trees killed or defoliated by forest insects and diseases are more susceptible to wildfire. As of 2012, just under 5 percent (more than 1 million acres) of Washington's 22.4 million acres of forestland showed some level of tree mortality, tree defoliation or foliar disease (Washington Department of Natural Resources, 2013).

Fuel moisture is expressed as a percentage of total saturation and varies with antecedent weather. Low fuel moistures indicate the probability of severe fires. Given the same weather conditions, moisture in fuels of different diameters changes at different rates. A 1,000-hour fuel, which has a 3- to 8-inch diameter, changes more slowly than a 1- or 10-hour fuel.

Topography

Topography can have a powerful influence on wildfire behavior. The movement of air over the terrain tends to direct a fire's course. Gulches and canyons can funnel air and act as a chimney, intensifying fire behavior and inducing faster rates of spread. Saddles on ridge tops offer lower resistance to the passage of air and will draw fires. Solar heating of drier, south-facing slopes produces upslope thermal winds that can complicate behavior.

Slope is an important factor. If the percentage of uphill slope doubles, the rate of spread of wildfire will likely double. On steep slopes, fuels on the uphill side of a fire are closer physically to the source of heat. Radiation preheats and dries the fuel, thus intensifying fire behavior. Fire travels downslope much more slowly than it does upslope, and ridge tops often mark the end of wildfire's rapid spread.

Weather

Of all the factors influencing wildfire behavior, weather is the most variable. Extreme weather leads to extreme fire events, and it is often a moderation of the weather that marks the end of a wildfire's growth

and the beginning of successful containment. High temperatures and low humidity can produce vigorous fire activity. The cooling and higher humidity brought by sunset can dramatically quiet fire behavior.

Fronts and thunderstorms can produce winds that are capable of radical and sudden changes in speed and direction, causing similar changes in fire activity. The rate of spread of a fire varies directly with wind velocity. Winds may play a dominant role in directing the course of a fire. Strong, dry winds produce extreme fire conditions. Such winds generally reach peak velocities during the night and early morning. The effect of wind on fire behavior is a primary safety concern for firefighters. In July 1994, a sudden change in wind speed and direction on Storm King Mountain in Colorado led to a blowup that claimed the lives of 14 firefighters. The most damaging firestorms are usually marked by high winds.

17.1.3 Wildland/Urban Interface Fires

WUI fires occur where combustible vegetation meets combustible structures, combining the hazards associated with wildfires and structure fires. These types of fires have increased dramatically in the last two decades as more and more people move to rural areas. Between 1970 and 1980, the rural population of the United States increased 23.4 percent, more than twice the gain of 11.4 percent for the nation as a whole. The hazard is bi-directional, wildfires can burn homes, and home fires can burn into wildlands.

WUI fires are increasing as more vacation homes are built and improved transportation systems allow more people to live outside city centers. The longer response times for these out-of-the-way locations gives the fire more time to get out of control, making these fires difficult to fight. Most firefighters are trained to fight either wildfires or structure fires. WUI fires require both skills, and it is very difficult to balance the two. When a WUI fire breaks out, the threat of extreme property and casualty losses often forces firefighters to focus their efforts on protecting homes and structures, sometimes at the expense of protecting wildland resources or working to slow the fire itself.

17.2 HAZARD PROFILE

17.2.1 Past Events

Structure fires

The largest conflagration in King County history is the 1889 Seattle fire, which is estimated to have consumed 60 acres of downtown.

On August 6, 1992, a series of fires began in the north Seattle area. Ultimately, 76 fires occurred, resulting in losses of over $30 million. On February 6, 1993, Paul Keller was arrested and charged with arson. He ultimately pled guilty to setting 32 of the fires.

Wildfires

Fire is a normal part of most forest and range ecosystems in temperate regions of the world. Fires historically burn on a fairly regular cycle, recycling carbon and nutrients stored in the ecosystem and strongly affecting the species within the ecosystem. Annual acreage consumed by wildfires in the lower 48 states dropped from about 40 to 50 million acres per year in the 1930s to under 5 million acres by 1970. A Western Washington study estimated that modern wildfires consume only about a tenth of the biomass each year that prehistoric fires burned.

According to the Washington State Emergency Management Division, the wildland fire season in Washington State typically begins in early July and lasts until late September. Climatic conditions such as drought, snowpack and localized weather can expand the length of the fire season. In July through early September, lightning strikes are the cause of most wildland fires in Washington State. Human-caused

fires are more prevalent at the beginning and end of the fire season. Only 30 percent of fires in the state are in Western Washington (EMD, 2013). None of the significant wildland fires since 1900 noted by the Washington State Emergency Management Division have occurred in King County.

The U.S. Department of the Interior maintains a database of federal agency records for 677,000 fires that occurred from 1980 through 2012 (USGS, 2013). There are 332 events listed that occurred in King County. Of these 332 events, 86 percent were attributed to human causes. Only six of the King County fires burned 10 acres or more; these are listed in Table 17 -90.

TABLE 17-90.
WILDFIRES IN KING COUNTY GREATER THAN 10 ACRES, 1980-2012

Forest Service Fire ID	Fire Name	Cause	Start Date	Area Burned (acres)
1483448	Crystal Mine	Natural	8/4/2009	25
285295	Unnamed	Human	5/24/1993	16
251146	Falls Creek	Human	7/26/1988	2,600
246258	Unnamed	Human	7/29/1988	70
246146	Unnamed	Human	9/11/1986	40
246145	Unnamed	Human	9/11/1986	40

Source: Federal Wildland Fire Occurrence Data, http://wildfire.cr.usgs.gov/firehistory/data.html

17.2.2 Location

The following sections describe two types of wildfire hazard mapping produced by the U.S. Forest Service and LANDFIRE (a program of the U.S. Forest Service and the U.S. Department of the Interior, under the direction of the Wildland Fire Leadership Council): fire regime mapping and fire behavior fuel model classifications.

Fire Regime Mapping

The LANDFIRE project produces maps of historical fire regimes and vegetation and maps of current vegetation and its departure from historical conditions. The maps categorize mean fire return intervals and fire severities into five fire regimes (Hann et al., 2004):

- Fire Regime I—0 to 35 year frequency, low to mixed severity
- Fire Regime II—0 to 35 year frequency, replacement severity
- Fire Regime III—35 to 200 year frequency, low to mixed severity
- Fire Regime IV—35 to 200 year frequency, replacement severity
- Fire Regime V—200+ year frequency, any severity.

These maps support fire and landscape management planning outlined in the goals of the National Fire Plan, Federal Wildland Fire Management Policy, and the Healthy Forests Restoration Act. Figure 17 -61 shows fire regimes in the planning area based on LANDFIRE models.

Insert Fire Regimes Map

Figure 17-61. Fire Regime Groups, 2008 LANDFIRE

Fire Behavior Fuel Model Classifications

Thirteen standard fire behavior fuel models (FBFM) serve as input to a mathematical model of surface fire behavior and spread. The fire behavior fuel model layer (FBFM13) represents the distribution of fuel loading among live and dead surface fuel components, size classes, and fuel types. The fuel models are described by the most common fire-carrying fuel type (grass, brush, timber litter, or slash), loading and surface area-to-volume ratio by size class and component, fuel bed depth, and moisture of extinction. The FBFM13 layer was produced by fire and fuels specialists based on vegetation type, cover, and height. The 13 classes, shown on Figure 17 -62, are defined as follows:

- FBFM 1—Surface fires that burn fine herbaceous fuels, cured and curing fuels, little shrub or timber present, primarily grasslands and savanna
- FBFM 2—Burns fine, herbaceous fuels, stand is curing or dead, may produce fire brands on oak or pine stands
- FBFM 3—Most intense fire of grass group, spreads quickly with wind, one third of stand dead or cured, stands average 3 feet tall
- FBFM 4—Fast spreading fire, continuous overstory, flammable foliage and dead woody material, deep litter layer can inhibit suppression
- FBFM 5—Low intensity fires, young, green shrubs with little dead material, fuels consist of litter from understory
- FBFM 6—Broad range of shrubs, fire requires moderate winds to maintain flame at shrub height, or will drop to the ground with low winds
- FBFM 7—Foliage highly flammable, allowing fire to reach shrub strata levels, shrubs generally 2 to 6 feet high
- FBFM 8—Slow, ground burning fires, closed canopy stands with short needle conifers or hardwoods, litter consisting mainly of needles and leaves, with little undergrowth, occasional flares with concentrated fuels
- FBFM 9—Longer flames, quicker surface fires, closed canopy stands of long-needles or hardwoods, rolling leaves in fall can cause spotting, dead-down material can cause occasional crowning
- FBFM 10—Surface and ground fire more intense, dead-down fuels more abundant, frequent crowning and spotting causing fire control to be more difficult
- FBFM 11—Fairly active fire, fuels consist of slash and herbaceous materials, slash originates from light partial cuts or thinning projects, fire is limited by spacing of fuel load and shade from overstory
- FBFM 12—Rapid spreading and high intensity fires, dominated by slash resulting from heavy thinning projects and clear-cuts, slash is mostly 3 inches or less
- FBFM 13—Fire spreads quickly through smaller material and intensity builds slowly as large material ignites, continuous layer of slash larger than 3 inches in diameter predominates, resulting from clear-cuts and heavy partial cuts, active flames sustained for long periods of time, fire is susceptible to spotting and weather conditions.

Insert FBFM Map

Figure 17-62. Fire Behavior Fuel Model, 2008 LANDFIRE

WUI Areas

The Washington Department of Natural Resources and its federal and local partners have determined that six areas in King County are at a high risk to wildfire: Black Diamond/Green River, Carnation, Cumberland, Kanaskat/Selleck, Lake Retreat/Rock Creek, North Bend and Snoqualmie Pass. According to the Washington State Emergency Management Division, areas of significant fire hazards are mapped based on fire behavior potential, fire protection capability, and risk to social, cultural and community resources. Risk is determined based on area fire history, type and density of vegetative fuels, extreme weather conditions, topography, number and density of structures and their distance from fuels, location of municipal watershed, and likely loss of housing or business (EMD, 2013). Figure 17 -63 shows WUI communities at risk.

17.2.3 Frequency

Natural fire rotation is defined as the number of years necessary for fires to burn over an area equal to that of the study area. Natural fire rotation is calculated from the historical record of fires by dividing the length of the record period in years by the percentage of total area burned during that period. It represents the average period between fires under a presumed historical fire regime. Since 1980, King County has seen an average of 10 wildfires per year. The vast majority of these fires burn less than 10 acres, with an overall average of 8.6 acres per incident. Fires occur annually, although fires that burn more than 10 acres have only occurred once every 5 years, on average.

17.2.4 Severity

Structure Fires

Injuries and casualties to the occupants of a structure are a primary concern in all structure fires. These events can also cause the release of hazardous materials and disconnect utility lines. Given the immediate response times to reported fires, the likelihood of injuries and casualties is minimal.

Wildfires

Potential losses from wildfire include human life, structures and other improvements, and natural resources. The effects of wildfires vary with intensity, area and time of year. The greatest short-term loss is the complete destruction of valuable resources, such as timber, wildlife habitat, recreation areas, and watersheds. In addition, wildfire can lead to ancillary impacts such as landslides in steep ravine areas and flooding due to the impacts of silt in local watersheds. Severe fires producing high soil temperatures create a water-repellent layer below the soil surface. The soil above this layer becomes highly prone to erosion, often resulting in mudslides. Long-term effects are reduced amounts of timber for commercial purposes and the reduction of travel and recreational activities in the affected area.

Health impacts, loss of life, and personal property losses occur as well. Smoke and air pollution from wildfires can be a health hazard, especially for sensitive populations including children, the elderly and those with respiratory and cardiovascular diseases. Wildfire may also threaten the health and safety of those fighting the fires. First responders are exposed to the dangers from the initial incident and after-effects from smoke inhalation and heat stroke. There are no recorded incidents of loss of life from wildfires in the planning area.

WUI Fires

The effects of WUI fires are the combined effects of both structure fires and wildfires.

Insert WUI Map

Figure 17-63. Wildland Urban Interface Communities at Risk

17.2.5 Warning Time

Wildfires are often caused by humans, intentionally or accidentally. There is no way to predict when one might break out. Since fireworks often cause brush fires, extra diligence is warranted around the Fourth of July when the use of fireworks is highest. Dry seasons and droughts are factors that greatly increase fire likelihood. Dry lightning may trigger wildfires. Severe weather can be predicted, so special attention can be paid during weather events that may include lightning. Reliable National Weather Service lightning warnings are available on average 24 to 48 hours prior to a significant electrical storm. If a fire does break out and spread rapidly, residents may need to evacuate within days or hours. A fire's peak burning period generally is between 1 p.m. and 6 p.m. Once a fire has started, fire alerting is reasonably rapid in most cases. The rapid spread of cellular and two-way radio communications in recent years has further contributed to a significant improvement in warning time.

17.3 SECONDARY HAZARDS

Wildfires can generate a range of secondary effects, which in some cases may cause more widespread and prolonged damage than the fire itself. Fires can cause direct economic losses in the reduction of harvestable timber and indirect economic losses in reduced tourism. Wildfires cause the contamination of reservoirs, destroy transmission lines and contribute to flooding. They strip slopes of vegetation, exposing them to greater amounts of runoff. This in turn can weaken soils and cause failures on slopes. Major landslides can occur several years after a wildfire. Most wildfires burn hot and for long durations that can bake soils, especially those high in clay content, thus increasing the imperviousness of the ground. This increases the runoff generated by storm events, thus increasing the chance of flooding.

17.4 EXPOSURE

17.4.1 Population

Population for three fire behavior fuel model classes was estimated using the structure count of buildings in the those areas and applying the census value for King County of 2.39 persons per household. These estimates are shown in Table 17 -91.

17.4.2 Property

Property damage from wildfires can be severe and can significantly alter entire communities. Table 17 -92 shows the number of structures in the planning area that are located in FBFM10 areas and their values. Parcels that intersect areas designated as FBFM10 were also analyzed to estimate the types of land uses that are exposed. Table 17 -93 shows the total area and percent of the total area of present land uses within the County that are exposed to this hazard. Based on these estimates, the majority of exposed parcels are uncategorized, which includes vacant and resource lands, making up 82.5 percent of the total percentage of exposed acres.

17.4.3 Critical Facilities and Infrastructure

In the event of wildfire, there would likely be little damage to most critical infrastructure. Most roads and railroads would be without damage except in the worst scenarios. Power lines are the most at risk to wildfire because most are made of wood and susceptible to burning. In the event of a wildfire, pipelines could provide a source of fuel and lead to a catastrophic explosion.

Currently there are two registered Tier II hazardous material containment sites in wildfire risk zones. During a fire event, hazardous materials storage containers could rupture due to heat and act as fuel for the fire, escalating the fire to unmanageable levels. In addition they could leak into surrounding areas, saturating soils and seeping into surface waters, and have a disastrous effect on the environment.

TABLE 17-91.
POPULATION WITHIN FIRE BEHAVIOR FUEL MODEL CLASSES

	FBFM 8			FBFM 9			FBFM 10		
		Population			Population			Population	
	Buildings	Number	% of Total	Buildings	Number	% of Total	Buildings	Number	% of total
Algona	56	133	4.34%	34	80	2.61%	1	2	0.07%
Auburn	2118	5,062	7.87%	1,416	3,384	5.26%	831	1,987	3.09%
Beaux Arts	77	183	63.17%	0	0	0.12%	35	84	28.90%
Bellevue	12387	29,605	22.41%	1,797	4,296	3.25%	3,108	7,428	5.62%
Black Diamond	483	1,154	27.67%	160	382	9.16%	174	417	10.00%
Bothell	1402	3,352	19.22%	318	760	4.36%	805	1,923	11.03%
Burien	3858	9,222	19.20%	776	1,856	3.86%	527	1,261	2.62%
Carnation	73	174	9.75%	33	79	4.43%	20	47	2.63%
Clyde Hill	470	1,123	37.69%	21	51	1.71%	71	169	5.68%
Covington	1139	2,722	15.04%	600	1,435	7.93%	496	1,185	6.55%
Des Moines	2005	4,792	16.12%	578	1,381	4.64%	233	557	1.87%
Duvall	385	920	12.92%	306	732	10.28%	115	274	3.85%
Enumclaw	55	130	1.18%	99	238	2.14%	12	29	0.26%
Federal Way	7387	17,654	19.68%	1,623	3,879	4.32%	1,611	3,851	4.29%
Hunts Point	58	138	34.97%	15	36	9.18%	65	155	39.26%
Issaquah	1550	3,703	11.53%	611	1,459	4.54%	2,323	5,552	17.28%
Kenmore	2418	5,779	27.30%	682	1,630	7.70%	855	2,043	9.65%
Kent	4432	10,592	8.79%	2,268	5,420	4.50%	700	1,672	1.39%
Kirkland	8495	20,304	24.84%	1,101	2,632	3.22%	2,102	5,025	6.15%
Lake Forest Park	1981	4,734	37.33%	392	937	7.39%	606	1,449	11.43%
Maple Valley	1193	2,852	11.93%	696	1,665	6.96%	971	2,321	9.71%
Medina	515	1,231	41.03%	106	254	8.46%	90	215	7.16%
Mercer Island	3219	7,693	33.86%	528	1,263	5.56%	759	1,813	7.98%
Milton	132	315	37.53%	34	80	9.57%	29	69	8.24%
Newcastle	956	2,284	21.46%	327	781	7.34%	555	1,327	12.47%
Normandy Park	869	2,077	32.71%	222	531	8.36%	237	565	8.90%
North Bend	334	798	13.25%	288	688	11.42%	174	415	6.89%
Pacific	140	336	5.03%	83	197	2.96%	26	62	0.92%
Redmond	4151	9,920	17.77%	840	2,007	3.59%	1,438	3,437	6.16%
Renton	4495	10,743	11.24%	1,985	4,744	4.97%	1,187	2,838	2.97%
Sammamish	3054	7,299	15.19%	1,912	4,570	9.51%	3,077	7,354	15.30%
SeaTac	1618	3,866	14.16%	381	911	3.34%	68	163	0.60%
Seattle	35929	85,871	13.70%	4,022	9,613	1.53%	1,866	4,460	0.71%
Shoreline	6994	16,715	31.14%	373	891	1.66%	637	1,523	2.84%
Skykomish	24	58	29.76%	22	52	26.74%	15	36	18.46%
Snoqualmie	513	1,225	10.47%	341	815	6.96%	1,312	3,136	26.80%
Tukwila	1032	2,466	12.87%	403	964	5.03%	78	186	0.97%
Woodinville	1088	2,601	23.66%	229	548	4.99%	607	1,451	13.20%
Yarrow Point	229	547	53.84%	22	49	4.87%	48	114	11.24%
Unincorporated	23,916	57,158	22.58	10,956	26,184	10.35	20,104	48,050	18.98
Total	0	0	**17.03**	0	0	**4.41**	0	0	**5.78**

TABLE 17-92.
EXPOSURE AND VALUE OF STRUCTURES IN FIRE BEHAVIOR FUEL MODEL 10

Jurisdiction	Buildings Exposed	Value Exposed			% of Total Assessed Value
		Structure	Contents	**Total**	
Algona	1	$559,149	$501,937	$1,061,086	0.12%
Auburn	831	$317,817,737	$217,531,531	$535,349,269	2.98%
Beaux Arts	35	$11,018,669	$5,673,332	$16,692,000	27.46%
Bellevue	3,108	$1,509,230,671	$945,579,131	$2,454,809,803	4.99%
Black Diamond	174	$39,981,778	$23,062,251	$63,044,029	10.50%
Bothell	805	$456,952,481	$285,205,179	$742,157,660	14.23%
Burien	527	$197,142,244	$111,255,205	$308,397,449	3.36%
Carnation	20	$4,659,491	$2,869,995	$7,529,486	2.29%
Clyde Hill	71	$29,187,580	$15,094,349	$44,281,929	5.24%
Covington	496	$115,673,609	$67,941,899	$183,615,508	6.44%
Des Moines	233	$91,168,128	$59,649,185	$150,817,314	2.63%
Duvall	115	$29,637,590	$16,365,487	$46,003,077	4.15%
Enumclaw	12	$5,137,151	$4,268,753	$9,405,904	0.35%
Federal Way	1,611	$819,238,817	$558,701,605	$1,377,940,422	7.21%
Hunts Point	65	$38,564,281	$19,779,401	$58,343,682	36.44%
Issaquah	2,323	$1,424,361,776	$884,923,306	$2,309,285,081	24.09%
Kenmore	855	$308,282,199	$207,070,791	$515,352,990	12.88%
Kent	700	$264,302,588	$153,916,322	$418,218,910	1.26%
Kirkland	2,102	$780,770,408	$474,554,227	$1,255,324,636	5.65%
Lake Forest Park	606	$144,517,863	$80,526,045	$225,043,908	10.16%
Maple Valley	971	$278,084,814	$163,304,692	$441,389,506	14.10%
Medina	90	$52,927,114	$27,958,454	$80,885,568	8.54%
Mercer Island	759	$329,083,653	$181,161,779	$510,245,432	7.73%
Milton	29	$14,143,707	$7,277,437	$21,421,144	15.22%
Newcastle	555	$257,589,652	$145,776,716	$403,366,369	17.79%
Normandy Park	237	$67,415,572	$37,281,237	$104,696,809	8.01%
North Bend	174	$59,810,831	$35,104,207	$94,915,038	6.53%
Pacific	26	$5,710,165	$2,926,205	$8,636,370	1.04%
Redmond	1,438	$877,719,228	$583,286,938	$1,461,006,166	6.29%
Renton	1,187	$499,543,690	$289,317,099	$788,860,788	3.05%
Sammamish	3,077	$1,137,923,516	$625,304,737	$1,763,228,253	18.95%
SeaTac	68	$48,495,237	$34,690,004	$83,185,241	1.10%
Seattle	1,866	$613,534,285	$370,053,744	$983,588,029	0.46%
Shoreline	637	$341,429,774	$240,860,617	$582,290,392	5.21%
Skykomish	15	$2,267,006	$1,598,125	$3,865,130	5.17%
Snoqualmie	1,312	$633,549,137	$414,235,373	$1,047,784,510	45.61%
Tukwila	78	$49,790,892	$37,038,874	$86,829,767	0.75%
Woodinville	607	$313,545,389	$222,768,946	$536,314,335	11.86%
Yarrow Point	48	$19,212,381	$10,072,547	$29,284,928	9.74%
Unincorporated	20,104	$5,592,636,023	$3,485,087,918	**$9,437,723,941**	21.12
Total	0	0	0	0	**5.24**

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.3.5 for a discussion of data limitations.

TABLE 17-93.
PRESENT LAND USE IN WILDFIRE HAZARD AREAS

Present Use Classification	Area (acres)	% of total
Agriculture	879	0.1%
Church, Welfare or Religious Service	1,095	0.1%
Commercial	7,072	0.6%
Education	4,048	0.4%
Governmental Services	2,143	0.2%
Industrial/Manufacturing	4,875	0.4%
Medical/Dental Services	203	0.0%
Mixed Use Development (Residential & Commercial)	41	0.0%
Mortuary/Cemetery/Crematory	448	0.0%
Nursing Home/Retirement Facility	211	0.0%
Park/Open Space/Golf Course	24,883	2.2%
Residential	139,593	12.5%
Terminal or Marina	2,200	0.2%
Utility/Easement/Right of Way	7949	0.7%
Water/Tideland/Wetland	217	0.0%
Uncategorized (includes vacant and resource lands)	920,792	82.5%
Total	**1,116,649**	**100%**

Source: Summarized from King, Pierce and Snohomish County parcel data. Acreage covers only mapped parcel extents and thus excludes many rights of way and major water features.

Table 17 -94 and Table 17 -95 identify critical facilities and infrastructure exposed to the wildfire hazard in the county. Spatial files of critical facility and infrastructure location and Anderson Fuel Class FBFM10 areas were intersected to determine exposure; however, the resolution of the hazard layer is not fine enough in scale for accurate building by building assessments. The exposure of critical facilities and infrastructure in the planning area is likely overestimated by this analysis.

TABLE 17-94.
CRITICAL FACILITIES IN FBFM10 AREAS

	Medical and Health	Government Functions	Protective Functions	Schools	Hazmat	Other Critical Functions	**Total**
Algona	0	0	0	0	0	0	**0**
Auburn	0	1	0	1	0	0	**2**
Beaux Arts Village	0	0	0	0	0	0	**0**
Bellevue	0	0	0	1	0	0	**1**
Black Diamond	0	0	0	0	0	0	**0**
Bothell	0	0	0	0	0	0	**0**
Burien	0	0	0	0	0	0	**0**
Carnation	0	0	0	0	0	0	**0**
Clyde Hill	0	0	0	0	0	0	**0**
Covington	0	0	0	0	0	0	**0**
Des Moines	0	0	0	0	0	0	**0**
Duvall	0	0	0	0	0	0	**0**
Enumclaw	0	0	0	0	0	0	**0**
Federal Way	0	0	0	0	0	1	**1**
Hunts Point	0	0	0	0	0	0	**0**
Issaquah	1	0	1	0	0	0	**2**
Kenmore	0	0	0	0	0	0	**0**
Kent	0	0	0	0	0	0	**0**
Kirkland	1	0	1	0	0	0	**2**
Lake Forest Park	0	0	0	0	0	0	**0**
Maple Valley	1	1	0	0	0	1	**3**
Medina	0	0	0	0	0	0	**0**
Mercer Island	0	0	0	0	0	0	**0**
Milton	0	0	0	0	0	0	**0**
Newcastle	0	0	0	0	0	0	**0**
Normandy Park	0	0	0	0	0	0	**0**
North Bend	0	0	0	0	0	0	**0**
Pacific	0	0	0	0	0	0	**0**
Redmond	0	0	0	0	0	0	**0**
Renton	0	0	0	0	0	0	**0**
Sammamish	0	0	0	0	0	0	**0**
SeaTac	0	0	0	0	0	0	**0**
Seattle	0	0	0	0	2	0	**2**
Shoreline	0	0	0	0	0	0	**0**
Skykomish	0	0	0	0	0	0	**0**
Snoqualmie	0	0	1	1	0	1	**3**
Tukwila	0	0	0	0	0	0	**0**
Woodinville	0	0	0	0	0	0	**0**
Yarrow Point	0	0	0	0	0	0	**0**
Unincorporated	0	0	3	5	0	0	**8**
Total	**3**	**2**	**6**	**8**	**2**	**3**	**24**

TABLE 17-95.
CRITICAL INFRASTRUCTURE IN FBFM10 AREAS

	Bridges	Transportation	Water Supply	Wastewater	Power	Communications	Dams	**Total**
Algona	0	0	0	0	0	0	0	**0**
Auburn	0	0	3	1	0	1	0	**5**
Beaux Arts Village	0	0	1	0	0	0	0	**1**
Bellevue	8	0	0	0	0	1	0	**9**
Black Diamond	0	0	0	0	0	0	0	**0**
Bothell	0	0	1	0	0	0	3	**4**
Burien	0	0	3	0	0	0	0	**3**
Carnation	0	0	0	0	0	0	0	**0**
Clyde Hill	0	0	0	0	0	0	0	**0**
Covington	0	0	0	0	0	0	0	**0**
Des Moines	3	0	0	2	0	0	0	**5**
Duvall	0	0	0	1	0	0	0	**1**
Enumclaw	0	0	0	0	0	0	0	**0**
Federal Way	0	0	0	0	0	0	1	**1**
Hunts Point	0	0	0	0	0	0	0	**0**
Issaquah	3	0	3	1	0	0	1	**8**
Kenmore	5	0	0	0	0	0	0	**5**
Kent	0	0	2	0	0	0	0	**2**
Kirkland	0	0	1	0	0	0	0	**1**
Lake Forest Park	0	0	0	0	0	0	0	**0**
Maple Valley	0	0	5	1	0	0	0	**6**
Medina	0	0	0	0	0	0	0	**0**
Mercer Island	0	0	0	0	0	0	0	**0**
Milton	0	0	0	0	0	0	0	**0**
Newcastle	0	0	0	0	0	0	0	**0**
Normandy Park	0	0	0	0	0	0	0	**0**
North Bend	0	0	1	0	1	0	0	**2**
Pacific	0	0	0	0	0	0	0	**0**
Redmond	0	0	2	1	0	0	0	**3**
Renton	1	0	0	0	0	0	0	**1**
Sammamish	1	0	0	0	0	0	1	**2**
SeaTac	1	0	0	0	0	0	0	**1**
Seattle	9	0	0	0	0	0	0	**9**
Shoreline	0	0	0	2	0	0	1	**3**
Skykomish	0	0	0	0	0	0	0	**0**
Snoqualmie	4	0	3	5	1	0	1	**14**
Tukwila	2	0	0	0	0	0	0	**2**
Woodinville	0	0	0	0	0	0	0	**0**
Yarrow Point	0	0	0	0	0	0	0	**0**
Unincorporated	69	3	22	6	0	9	7	**116**
Total	**106**	**3**	**47**	**20**	**2**	**11**	**15**	**204**

17.4.4 Environment

Fire is a natural and critical ecosystem process in most terrestrial ecosystems, dictating in part the types, structure, and spatial extent of native vegetation. However, wildfires can cause severe environmental impacts:

- Damaged Fisheries—Critical fisheries can suffer from increased water temperatures, sedimentation, and changes in water quality.
- Soil Erosion—The protective covering provided by foliage and dead organic matter is removed, leaving the soil fully exposed to wind and water erosion. Accelerated soil erosion occurs, causing landslides and threatening aquatic habitats.
- Spread of Invasive Plant Species—Non-native woody plant species frequently invade burned areas. When weeds become established, they can dominate the plant cover over broad landscapes, and become difficult and costly to control.
- Disease and Insect Infestations—Unless diseased or insect-infested trees are swiftly removed, infestations and disease can spread to healthy forests and private lands. Timely active management actions are needed to remove diseased or infested trees.
- Destroyed Endangered Species Habitat—Catastrophic fires can have devastating consequences for endangered species.
- Soil Sterilization—Topsoil exposed to extreme heat can become water repellant, and soil nutrients may be lost. It can take decades or even centuries for ecosystems to recover from a fire. Some fires burn so hot that they can sterilize the soil.

Many ecosystems are adapted to historical patterns of fire occurrence. These patterns, called "fire regimes," include temporal attributes (e.g., frequency and seasonality), spatial attributes (e.g., size and spatial complexity), and magnitude attributes (e.g., intensity and severity), each of which have ranges of natural variability. Ecosystem stability is threatened when any of the attributes for a given fire regime diverge from its range of natural variability.

17.5 VULNERABILITY

Structures, above-ground infrastructure, critical facilities and natural environments are all vulnerable to the wildfire hazard. There is currently no validated damage function available to support wildfire mitigation planning. Except as discussed in this section, vulnerable populations, property, infrastructure and environment are assumed to be the same as described in the section on exposure.

17.5.1 Population

Approximately 3,500 to 4,000 people die every year from fire, and thousands of people are injured. In Washington State over the last 20 years 1,195 people lost their lives in fire. King County averages about 11 fire deaths per year. Cooking, smoking, heating, electrical, and arson are some of the major causes of fire in general, and careless smoking is the leading cause of fire deaths. About one-third of all fires occur in residential properties; one-third involves natural vegetation (brush or wildland); and the remaining third involves vehicles, outside equipment and storage, and other locations. Most fires are human-caused and are preventable; only a small percentage of fires are due to natural acts such as lightning.

Smoke and air pollution from wildfires can be a severe health hazard, especially for sensitive populations, including children, the elderly and those with respiratory and cardiovascular diseases. Smoke generated by wildfire consists of visible and invisible emissions that contain particulate matter (soot, tar, water vapor, and minerals), gases (carbon monoxide, carbon dioxide, nitrogen oxides), and toxics

(formaldehyde, benzene). Emissions from wildfires depend on the type of fuel, the moisture content of the fuel, the efficiency (or temperature) of combustion, and the weather. Public health impacts associated with wildfire include difficulty in breathing, odor, and reduction in visibility. Wildfire also threaten the health and safety of those fighting the fires. First responders are exposed to the dangers from the initial incident and after-effects from smoke inhalation and heat stroke.

17.5.2 Property

Loss estimations for the wildfire hazard are not based on damage functions, because no such damage functions have been generated. Instead, loss estimates were developed representing 10 percent, 30 percent and 50 percent of the assessed value of exposed structures. This allows emergency managers to select a range of economic impact based on an estimate of the percent of damage to the general building stock. Damage in excess of 50 percent is considered to be substantial by most building codes and typically requires total reconstruction of the structure. Table 17 -96 lists the loss estimates for the general building stock for assets within jurisdictions that have an exposure to a FBFM10 hazard severity zone.

17.5.3 Critical Facilities and Infrastructure

Critical facilities of wood frame construction are especially vulnerable during wildfire events. In the event of wildfire, there would likely be little damage to most infrastructure. Most roads and railroads would be without damage except in the worst scenarios. Power lines are the most at risk from wildfire because most poles are made of wood and susceptible to burning. Fires can create conditions that block or prevent access and can isolate residents and emergency service providers. Wildfire typically does not have a major direct impact on bridges, but it can create conditions in which bridges are obstructed. Many bridges in areas of high to moderate fire risk are important because they provide the only ingress and egress to large areas and in some cases to isolated neighborhoods.

17.6 FUTURE TRENDS IN DEVELOPMENT

The highly urbanized portions of the planning area have little or no wildfire risk exposure. Urbanization tends to alter the natural fire regime, and can create the potential for the expansion of urbanized areas into wildland areas. The expansion of the wildland urban interface can be managed with strong land use and building codes. The planning area is well equipped with these tools and this planning process has asked each planning partner to assess its capabilities with regards to the tools. As the planning area experiences future growth, it is anticipated that the exposure to this hazard will remain as assessed or even decrease over time due to these capabilities.

Wildfire risk exposure exists in more rural areas of the County and is likely to increase as development continues. Growth Management Act regulations, however, will slow the rate of growth in these areas as most development is targeted in already urbanized areas.

17.7 SCENARIO

A major conflagration in the planning area might begin with a wet spring, adding to fuels already present on the forest floor. Flashy fuels would build throughout the spring. The summer could see the onset of insect infestation. A dry summer could follow the wet spring, exacerbated by dry hot winds. Carelessness with combustible materials or a tossed lit cigarette, or a sudden lighting storm could trigger a multitude of small isolated fires.

**TABLE 17-96.
LOSS ESTIMATES FOR WILDFIRE**

		Estimated Loss Potential from Wildfire		
	Exposed Value	10% Damage	30% Damage	50% Damage
Algona	$1,061,086	$106,109	$318,326	$530,543
Auburn	$535,349,269	$53,534,927	$160,604,781	$267,674,634
Beaux Arts	$16,692,000	$1,669,200	$5,007,600	$8,346,000
Bellevue	$2,454,809,803	$245,480,980	$736,442,941	$1,227,404,901
Black Diamond	$63,044,029	$6,304,403	$18,913,209	$31,522,014
Bothell	$742,157,660	$74,215,766	$222,647,298	$371,078,830
Burien	$308,397,449	$30,839,745	$92,519,235	$154,198,725
Carnation	$7,529,486	$752,949	$2,258,846	$3,764,743
Clyde Hill	$44,281,929	$4,428,193	$13,284,579	$22,140,964
Covington	$183,615,508	$18,361,551	$55,084,652	$91,807,754
Des Moines	$150,817,314	$15,081,731	$45,245,194	$75,408,657
Duvall	$46,003,077	$4,600,308	$13,800,923	$23,001,539
Enumclaw	$9,405,904	$940,590	$2,821,771	$4,702,952
Federal Way	$1,377,940,422	$137,794,042	$413,382,127	$688,970,211
Hunts Point	$58,343,682	$5,834,368	$17,503,105	$29,171,841
Issaquah	$2,309,285,081	$230,928,508	$692,785,524	$1,154,642,541
Kenmore	$515,352,990	$51,535,299	$154,605,897	$257,676,495
Kent	$418,218,910	$41,821,891	$125,465,673	$209,109,455
Kirkland	$1,255,324,636	$125,532,464	$376,597,391	$627,662,318
Lake Forest Park	$225,043,908	$22,504,391	$67,513,172	$112,521,954
Maple Valley	$441,389,506	$44,138,951	$132,416,852	$220,694,753
Medina	$80,885,568	$8,088,557	$24,265,670	$40,442,784
Mercer Island	$510,245,432	$51,024,543	$153,073,630	$255,122,716
Milton	$21,421,144	$2,142,114	$6,426,343	$10,710,572
Newcastle	$403,366,369	$40,336,637	$121,009,911	$201,683,184
Normandy Park	$104,696,809	$10,469,681	$31,409,043	$52,348,405
North Bend	$94,915,038	$9,491,504	$28,474,511	$47,457,519
Pacific	$8,636,370	$863,637	$2,590,911	$4,318,185
Redmond	$1,461,006,166	$146,100,617	$438,301,850	$730,503,083
Renton	$788,860,788	$78,886,079	$236,658,236	$394,430,394
Sammamish	$1,763,228,253	$176,322,825	$528,968,476	$881,614,126
SeaTac	$83,185,241	$8,318,524	$24,955,572	$41,592,620
Seattle	$983,588,029	$98,358,803	$295,076,409	$491,794,015
Shoreline	$582,290,392	$58,229,039	$174,687,117	$291,145,196
Skykomish	$3,865,130	$386,513	$1,159,539	$1,932,565
Snoqualmie	$1,047,784,510	$104,778,451	$314,335,353	$523,892,255
Tukwila	$86,829,767	$8,682,977	$26,048,930	$43,414,883
Woodinville	$536,314,335	$53,631,434	$160,894,301	$268,157,168
Yarrow Point	$29,284,928	$2,928,493	$8,785,478	$14,642,464
Unincorporated	$9,437,723,941	$943,772,394	$2,831,317,182	$4,718,861,971
Total	0	0	0	0

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. See Section 5.3.5 for a discussion of data limitations.

The embers from these smaller fires could be carried miles by hot, dry winds. The deposition zone for these embers would be deep in the forests and WUI zones. Fires that start in flat areas move slower, but wind still pushes them. It is not unusual for a wildfire pushed by wind to burn the ground fuel and later climb into the crown and reverse its track. This is one of many ways that fires can escape containment, typically during periods when response capabilities are overwhelmed. These new small fires would most likely merge. Suppression resources would be redirected from protecting the natural resources to saving more remote subdivisions.

The worst-case scenario would include an active fire season throughout the American west, spreading resources thin. Firefighting teams would be exhausted or unavailable. Many federal assets would be responding to other fires that started earlier in the season. While local fire districts would be extremely useful in the WUI areas, they have limited wildfire capabilities or experience, and they would have a difficult time responding to the ignition zones. Even though the existence and spread of the fire is known, it may not be possible to respond to it adequately, so an initially manageable fire can become out of control before resources are dispatched.

To further complicate the problem, heavy rains could follow, causing flooding and landslides and releasing tons of sediment into rivers, permanently changing floodplains and damaging sensitive habitat and riparian areas. Such a fire followed by rain could release millions of cubic yards of sediment into streams for years, creating new floodplains and changing existing ones. With the forests removed from the watershed, stream flows could easily double. Floods that could be expected every 50 years may occur every couple of years. With the streambeds unable to carry the increased discharge because of increased sediment, the floodplains and floodplain elevations would increase.

17.8 ISSUES

Factors related to the fighting of fires include access, firebreaks, proximity of water sources, distance from a fire station, and available firefighting personnel and equipment. Reviewing past WUI fires shows that many structures are destroyed or damaged for one or more of the following reasons:

- Combustible roofing material
- Wood construction
- Structures with no defensible space
- Fire department with poor access to structures
- Subdivisions located in heavy natural fuel types
- Structures located on steep slopes covered with flammable vegetation
- Limited water supply
- Winds over 30 miles per hour.

Road access is a major issue for all emergency service providers. As development encroaches into rural areas, the number of houses without adequate tum-around space is increasing. Developers are not required to provide adequate space for emergency vehicles in single-family residential homes, causing emergency workers to have difficulty doing their jobs because they cannot access houses. As fire trucks are large, firefighters are challenged by narrow roads and limited access. When there is doubt concerning the stability of a residential bridge, or adequate tum around space, firefighters can work to remove the occupants but cannot save the structure.

Fires may become conflagration fires caused by reduced setbacks between structures. Narrow setbacks also prevent fire crews from safely laddering the sides of buildings.

Firefighters in remote and rural areas are faced with limited water supply and lack of hydrant taps. Rural areas are adapting to these conditions by developing a secondary water source. Areas that once were considered rural during county control became urban with incorporation and annexation, coupled with development.

The following steps should be accomplished to preclude major loss of life and reduce the actual number of wildfires and WUI fires:

- Citizens should know the proper way to handle fire. Public education programs on fire safety, fire alarms and fire response are important. People should also be encouraged to purchase fire insurance and understand building codes.
- Since people start the vast majority of wildfires, wildfire prevention education and enforcement programs can significantly reduce the total number of wild land fires.
- Arson investigation has been a significant factor in the reduction of urban fires. Investigators and fire crews work together to convict and or deter more arsonists than ever before.
- An effective early fire detection program and an emergency communications system are essential. The importance of immediately reporting any wildfire must be impressed upon local residents and persons using forest areas.
- An effective warning system is essential to notify local inhabitants and persons in the area of the fire. An evacuation plan detailing primary and alternate escape routes is also essential.
- Fire-safe development planning should be done with local government planners to reduce the risk to local residents and businesses.
- Road development criteria should ensure adequate escape routes for new sections of development in forest areas.
- Road closures should be increased during peak fire periods to reduce the access to fire-prone areas.

CHAPTER 18.

HAZARDS OF INTEREST

The hazards of concern that are assessed in Chapter 9. through Chapter 17. and rated and ranked in Chapter 19. are those that present significant risks in King County. Additional hazards of interest were identified by the Steering Committee as having some potential to impact the planning area, but at a much lower risk level than the hazards of concern.

This chapter presents a short profile of each hazard of interest, including a qualitative discussion of its potential to impact King County. No formal risk assessment of these hazards was performed, as they are more thoroughly addressed in other emergency management planning efforts. However, County, city and special purpose district staff and residents should be aware of these hazards and should take steps to reduce the risks they present whenever it is practical to do so.

18.1 HEALTH HAZARDS

Health hazards that affect the residents of King County may arise in a variety of situations, such as during a communicable disease outbreak, after a natural disaster, or as the result of a bioterrorism incident. All populations in King County are susceptible to bioterrorism or pandemic events. Populations who are young or elderly or have compromised immune systems are likely to be more vulnerable.

18.1.1 Epidemic or Pandemic

The U.S. Center for Disease Control defines an outbreak as the occurrence of more cases of disease than normally expected within a specific place or group of people over a given period of time. State and local regulations require immediate reporting of any known or suspected outbreaks by health care providers, health care facilities, laboratories, veterinarians, schools, child day care facilities, and food service establishments. An epidemic is a localized outbreak that spreads rapidly and affects a large number of people or animals in a community. A pandemic is an epidemic that occurs worldwide or over a very large area and affects a large number of people or animals.

The Washington Emergency Management Division has identified the following as human diseases that could contribute to a serious epidemic in the area:

- Methicillin-resistant staphylococcus aureus
- West Nile virus
- Influenza
- H1N1 influenza
- Severe acute respiratory syndrome (SARS)
- Measles
- Hepatitis
- Tuberculosis
- E. coli
- Lye disease

- Hantavirus
- HIV/AIDS
- Leptospirosis.

According to Washington State's Hazard Mitigation Plan, factors in Washington that heighten the probability of occurrences of such events include large numbers of travelers arriving via the region's air and sea ports, the transportation of infected animals into the area, contaminated garbage or other waste washing ashore, or disease transmission through individuals transporting or coming into contact with hospitalized or nursing-home-bound patients (EMD, 2013).

18.1.2 Bioterrorism

The federal Centers for Disease Control and Prevention (CDC) defines bioterrorism as the deliberate use of viruses, bacteria or other agents to cause illness or death in people, animals or plants (CDC, 2007). Biological agents pose a serious threat due to their accessibility and the rapid manner in which they can be spread within a population. The most commonly discussed agents include anthrax (sometimes found in sheep and cattle), tularemia (rabbit fever), cholera, the plague (sometimes found in prairie dog colonies), and botulism (found in improperly canned food). A biological incident is likely to be first detected in a hospital emergency room, medical examiner's office, or within the public health community long after the terrorist act. The consequences of such an act will require communities to provide massive reactive and precautionary treatments to exposed populations and to stage mass fatality management and environmental health clean-up operations, procedures and plans.

Categories of Biological Agents

The CDC outlines three categories by which biological agents can be defined (CDC, 2007):

- Category A—These high-priority agents include organisms or toxins that pose the highest risk to the public and national security because:
  - They can be easily spread or transmitted from person to person
  - They result in high death rates and have the potential for major public health impact
  - They might cause public panic and social disruption
  - They require special action for public health preparedness.
- Category B—These agents are the second highest priority because:
  - They are moderately easy to spread
  - They result in moderate illness rates and low death rates
  - They require specific enhancements of CDC's laboratory capacity and enhanced disease monitoring.
- Category C—These third highest priority agents include emerging pathogens that could be engineered for mass spread in the future because:
  - They are easily available
  - They are easily produced and spread
  - They have potential for high morbidity and mortality rates and major health impact.

Event Profile

FEMA characterizes an event profile for a terrorist attack involving a biological agent as follows:

- **Application Mode**—Liquid or solid contaminants can be dispersed using sources such as munitions, covert deposits or moving sprayers. Biological agents may also be introduced into food and water supplies, or through direct application to skin.
- **Duration/Threat Impact**—Biological agents may pose viable threats for hours to years, depending on the agent and the conditions in which it exists.
- **Severity**—Depending on the agent used and the effectiveness with which it is deployed, contamination can be spread via wind and water. Infection can spread via human or animal vectors.
- **Mitigating and Exacerbating Conditions**—The altitude of release can affect dispersion; sunlight is destructive to many bacteria and viruses; light to moderate wind will disperse agents but higher winds can break up aerosol clouds; the micro-meteorological effects of buildings and terrain can influence aerosolization and travel of agents

Seattle and King County Public Health has developed a bioterrorism response plan in partnership with the Washington State Department of Health and the CDC. In the event of an attack in King County, the public would be informed through the news media, the Public Health website and the King County website regarding the best steps to take to protect one’s health.

18.2 CYBERSECURITY

A cyber-attack is an attack intended to create physical effects or to manipulate, disrupt or delete data. It might range from a denial-of-service operation that temporarily prevents access to a website, to an attack on a power turbine that causes physical damage and an outage lasting for days. Cyber espionage refers to intrusions into networks to access sensitive diplomatic, military or economic information (Clapper, 2013). Cyber-attacks on infrastructure can originate from adversaries such as hostile governments, criminal organizations, or lone individuals. It is important to differentiate a cyber-attack from cyber-terrorism. While there have been cyber-attacks against governments, they have not been for the purpose of gaining warfare information or access. FEMA characterizes an event profile for a cyber-attack or cyber-espionage as follows:

- **Application Mode**—Unlawful attacks and threats of attack against computers, networks and information stored therein
- **Duration/Threat Impact**—Minutes to days
- **Severity**—Generally no direct effects on built environment; secondary impact from system attacked (e.g., computerized control system regulating water release)
- **Mitigating and Exacerbating Conditions**—Inadequate security can facilitate access to critical computer systems, allowing them to be used to conduct attacks, or gather information to support other terrorist-related activities.

Cyber criminals threaten U.S. economic interests. The Office of the Comptroller of the Currency, which regulates national banks, has issued warnings to banks and business of their potential risk. Since September 2012, attacks have been increasingly aimed at businesses with fewer than 250 employees (Associated Press, 2013). Financial institutions are reluctant to provide details and information about cyber-attacks for fear of becoming a greater target. Software manufactures estimate that cyber-attacks against U.S. businesses have increased 42 percent over the course of the last year.

Cyber criminals sell tools via a growing black market that enable access to critical infrastructure systems. Some commercial companies sell computer intrusion kits on the open market that can give governments and cyber criminals the ability to steal, manipulate or delete information on targeted systems. Other companies sell professional-quality technologies to support cyber operations—often branding these tools as lawful-intercept or defensive security research products. Many individuals, groups and foreign governments already use some of these tools to target national and local systems.

A March 2013 report by the National Intelligence Agency to the Senate Intelligence Committee indicated only a remote chance over the next two years of a major cyber-attack against U.S. critical infrastructure such as a regional power grid. Less sophisticated attacks, such as denial-of-service attacks against bank websites, could be more likely (Strobel and Wilson, 2013).

18.3 TERRORISM

Acts of terrorism are intentional, criminal, malicious acts. Terrorism is defined as the unlawful use or threatened use of force or violence against people or property with the intention of intimidating or coercing societies or governments. The Federal Bureau of Investigation (FBI) categorizes terrorism in the U.S. primarily as one of two types:

- Domestic terrorism involves groups or individuals whose terrorist activities are directed at elements of our government or population without foreign direction. The bombing of the Alfred P. Murrah federal building in Oklahoma City is an example of domestic terrorism. The FBI is the primary response agency for domestic terrorism. The FBI coordinates domestic preparedness programs and activities of the United States to limit acts posed by terrorists, including the use of weapons of mass destruction.
- International terrorism involves groups or individuals whose terrorist activities are foreign based and/or directed by countries or groups outside the United States, or whose activities transcend national boundaries. Examples include the 1993 bombing of the World Trade Center, the U.S. Capitol, and Mobil Oil’s corporate headquarters and the attacks of September 11, 2001 at the World Trade Center and the Pentagon.

Many people equate terrorism with the use of weapons of mass destruction, such as chemical, biological, radiological, nuclear and explosive weapons. However, terrorism also includes arson, incendiary and explosive devices, school shootings, sabotage, hazardous materials releases, agro-terrorism and cyber-terrorism. Terrorism can be distinguished from other types of hazards by three important considerations:

- In the case of chemical, biological, and radioactive agents, their presence may not be immediately obvious, making it difficult to determine when and where they were released, who was exposed, and what danger is present for first responders.
- There is limited scientific understanding of how these agents affect the population at large.
- Terrorism evokes very strong emotional reactions, ranging from anxiety, to fear to anger, to despair to depression.

Terrorists often choose targets that offer limited danger to themselves and areas with relatively easy public access. They look for visible targets where they can avoid detection before and after an attack, such as international airports, large cities, major special events, and high-profile landmarks. Two terrorist techniques of growing concern in the public safety arena are the targeting of first responders employing secondary explosive devices and hoaxes involving weapons of mass destruction.

18.3.1 Past Events

There have been several instances of terrorism in western Washington (King County Office of Emergency Management, 2009):

- In June 2011, the FBI raided a warehouse in Seattle that housed two suspects who had arranged to purchase weapons from an anonymous informant in contact with the Seattle Police Department. The two were seeking to purchase automatic machine guns and grenades in preparation for an attack on a military recruiting station in Seattle (FBI, 2011). The men were charged with conspiracy to murder officers and employees of the U.S. government, conspiracy to use a weapon of mass destruction, and possession of firearms in furtherance of crimes of violence. One was also charged with two counts of illegal possession of firearms.
- In July 2006, a gunman fired on women at the Jewish Federation of Greater Seattle.
- From January 2000 to December 2002 there were numerous reported instances of a biological white powder. Individuals in Seattle, Federal Way, Tukwila, Port of Seattle and other cities were affected. There were no reports of injuries or death, but the incidents did cause financial implications through the payment of overtime and service disruptions.
- In May 2001 an incendiary device was deployed at the University of Washington’s Urban Horticultural Center by the domestic terrorist group Earth Liberation Front. The firebomb caused over $5 million in damage.
- In December 1999, a man was arrested by U.S. Customs officials while entering the United States in Port Angeles, Washington, aboard a ferry from Victoria, British Columbia. He was subsequently charged with smuggling explosive material into the United States. The CIA noted that the timing devices and nitroglycerine in his possession were the “signature devices” of groups affiliated with Al-Qaeda.
- The FBI and Bellingham Police interdicted a group of terrorists affiliated with the Washington State Militia on July 27, 1996. The group planned to bomb various infrastructure targets including a radio tower, bridge, and a train tunnel while the train was inside.
- In 1995 a chemical explosive device was detonated at the Burien District Court.
- The American Front Skinheads detonated pipe bombs in Tacoma on July 20 and 22, 1993.

18.3.2 Incendiary Devices

Incendiary devices are mechanical, electrical, or chemical devices used to intentionally initiate combustion and start fires. Their purpose is to destroy and ignite their target or other nearby materials or structures or to provide a diversion preceding an even larger terrorist or criminal act. These devices are detonated singularly or in series. Bombs are terrorist’s weapon of choice. Explosive incidents account for 70 percent of all terrorist attacks worldwide. According to the FBI, 172 improvised explosive devices were reported in the United States between October 2012 and April 2013.

From the standpoint of structural design, the vehicle bomb is the most important consideration and has been a favorite tactic of terrorists. Ingredients for homemade bombs are easily obtained on the open market, as are the techniques for making bombs. The severity of impact is based on the amount and type of explosive materials used. The size of vehicle affects how close it can get to a target and how large an explosive device it can deliver, as shown on Figure 18 -64

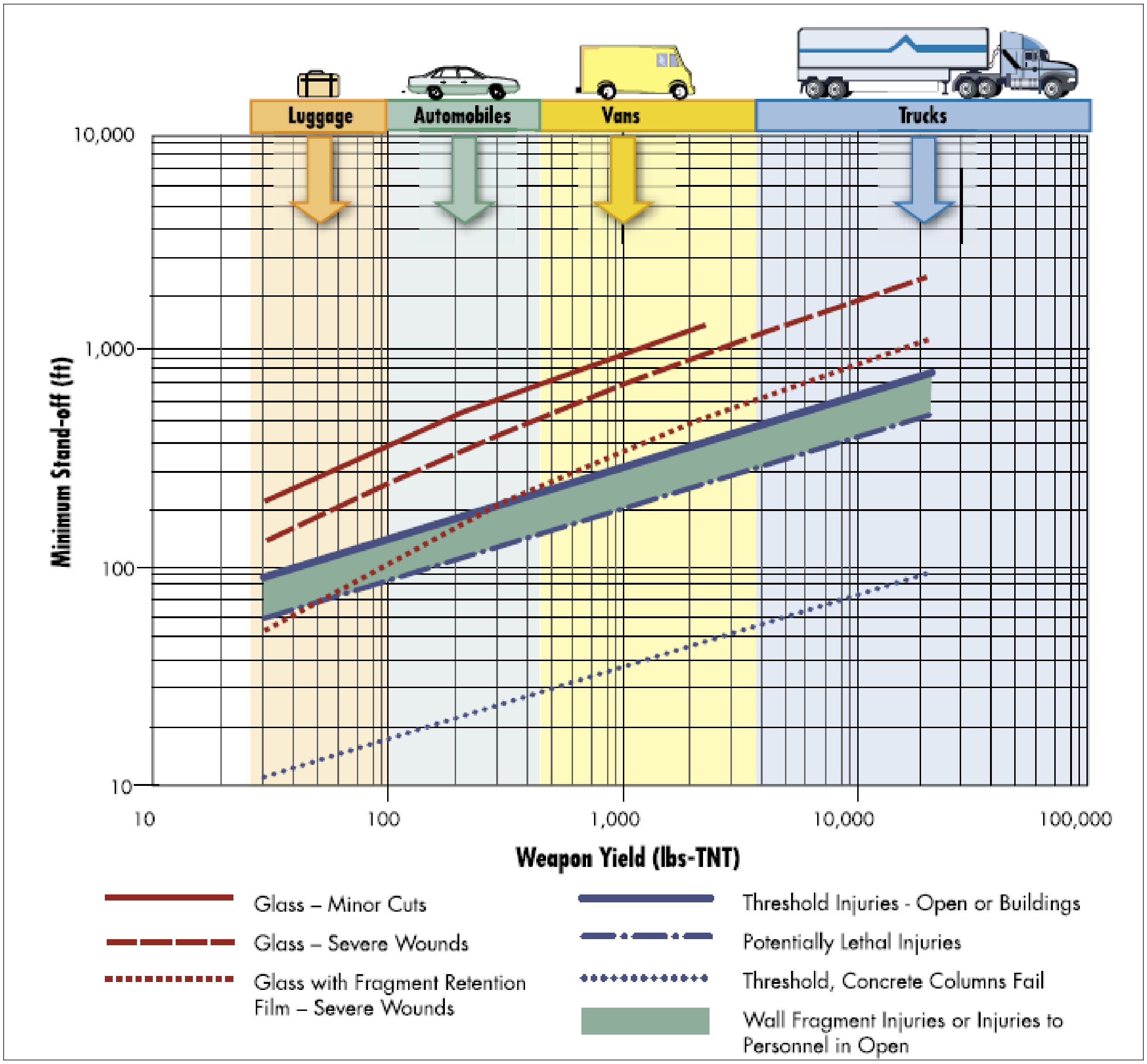


Figure 18-64. Damage Potential from Explosives Based on Delivery Vehicle

FEMA characterizes an event profile for a terrorist attack involving an incendiary attack as follows:

- **Application Mode**—Initiation of fire or explosion on or near target via direct contact or remotely via projectile.
- **Duration/Threat Impact**—Generally minutes to hours.
- **Severity**—Extent of damage is determined by type and quantity of device, accelerant, and materials present at or near target. Effects generally static other than cascading consequences, incremental structural failure, etc.
- **Mitigating and Exacerbating Conditions**—Mitigation factors include built-in fire detection and protection systems and fire-resistive construction techniques, or security measures which reduce exposure. Inadequate security can allow easy access to target, easy concealment of an incendiary device, and undetected initiation of a fire. Non-compliance with fire and building codes, as well as failure to maintain existing fire protection systems, can substantially increase the effectiveness of a fire weapon.

18.3.3 Potential Targets

Terrorist targets are often located near high traffic/high-visibility routes with convenient transportation access. They may become more appealing when high profile personalities and dignitaries visit them. Examples of targets include:

- Government office buildings, courthouses, schools, hospitals, and shopping centers
- Symbolic targets whose operations, practices or associations represent values in conflict with the terrorists ideology
- Dams, water supplies, electrical and gas distribution systems, pipelines, chemical facilities
- Military installations and suppliers
- Railheads, interstate highways, tunnels, airports, ferries, bridges, seaports, overpasses
- Recreational facilities such as sports stadiums, theaters, parks, casinos, concert halls, public venues
- Financial institutions and banks
- Sites of historical and symbolic significance
- Scientific research facilities, academic institutions, museums
- Telecommunications, newspapers, radio and television stations
- Chemical, industrial, and petroleum plants
- Business offices, convention centers
- Law, fire, emergency medical services, and responder facilities and operations centers
- Special events, parades, religious services, festivals, celebrations
- Planned Parenthood facilities and abortion clinics.

King County contains a large number of all of these potential targets.

18.3.4 Potential Economic Impacts

Economic impacts from terrorist events could be significant:

- The cost of a terrorist act would be felt in terms of loss of life and property, disruption of business activity and long-term emotional impacts. Recovery would take significant resources and expense at the local level.
- Utility losses could cause a reduction in employment, wholesale and retail sales, utility repairs, and increased medical risks. Local governments may lose sales tax, and the finances of private utility companies and the businesses that rely on them would be disrupted.
- The economic impact of computer security breaches associated with data and telecommunications losses can be staggering.
- The economic impacts should a transportation facility be rendered impassable would be significant. The loss of a roadway or railway would have serious effects on the economy and local jurisdictions' ability to provide services. Loss of travel routes would result in loss of commerce, and could impact the ability to provide emergency services to citizens by delaying response times or limiting routes for equipment such as fire apparatus, police vehicles, and ambulances. The ability to receive fuel deliveries would also be impacted.

CHAPTER 19.

PLANNING AREA RISK RANKING

A risk ranking was performed for the hazards of concern described in this plan. This risk ranking assesses the probability of each hazard's occurrence as well as its likely impact on the people, property, and economy of the planning area. The risk ranking was conducted via facilitated brainstorming sessions with the Steering Committee. Estimates of risk were generated with data from Hazus-MH using methodologies promoted by FEMA. The results are used in establishing mitigation priorities.

19.1.1 Probability of Occurrence

The probability of occurrence of a hazard is indicated by a probability factor based on likelihood of annual occurrence:

- High—Hazard event is likely to occur within 25 years (Probability Factor = 3)
- Medium—Hazard event is likely to occur within 100 years (Probability Factor =2)
- Low—Hazard event is not likely to occur within 100 years (Probability Factor =1)
- No exposure—There is no probability of occurrence (Probability Factor = 0)

The assessment of hazard frequency is generally based on past hazard events in the area. Table 19 -97 summarizes the probability assessment for each hazard of concern for this plan.

TABLE 19-97.
PROBABILITY OF HAZARDS

Hazard Event	Probability (high, medium, low)	Probability Factor
Avalanche	High	3
Dam Failure	Low	1
Earthquake	High	3
Flood	High	3
Landslide	High	3
Severe Weather	High	3
Severe Winter Weather	High	3
Tsunami	Low	1
Volcano	Low	1
Wildfire	Medium	2

19.1.2 Impact

Hazard impacts were assessed in three categories: impacts on people, impacts on property and impacts on the local economy. Numerical impact factors were assigned as follows:

- **People**—Values were assigned based on the percentage of the total ***population exposed*** to the hazard event. The degree of impact on individuals will vary and is not measurable, so the calculation assumes for simplicity and consistency that all people exposed to a hazard because they live in a hazard zone will be equally impacted when a hazard event occurs. It should be noted that planners can use an element of subjectivity when assigning values for impacts on people. Impact factors were assigned as follows:
  - High—30 percent or more of the population is exposed to a hazard (Impact Factor = 3)
  - Medium—15 percent to 29 percent of the population is exposed to a hazard (Impact Factor = 2)
  - Low—14 percent or less of the population is exposed to the hazard (Impact Factor = 1)
  - No impact—None of the population is exposed to a hazard (Impact Factor = 0)
- **Property**—Values were assigned based on the percentage of the total ***property value exposed*** to the hazard event:
  - High—25 percent or more of the total assessed property value is exposed to a hazard (Impact Factor = 3)
  - Medium—10 percent to 24 percent of the total assessed property value is exposed to a hazard (Impact Factor = 2)
  - Low—9 percent or less of the total assessed property value is exposed to the hazard (Impact Factor = 1)
  - No impact—None of the total assessed property value is exposed to a hazard (Impact Factor = 0)
- **Economy**—Values were assigned based on the percentage of the total ***property value vulnerable*** to the hazard event. Values represent estimates of the loss from a major event of each hazard in comparison to the total assessed value of the property exposed to the hazard. For some hazards, such as wildfire, landslide and severe weather, vulnerability was considered to be the same as exposure due to the lack of loss estimation tools specific to those hazards. Loss estimates separate from the exposure estimates were generated for the earthquake and flood hazards using Hazus-MH.
  - High—Estimated loss from the hazard is 15 percent or more of the total assessed property value (Impact Factor = 3)
  - Medium—Estimated loss from the hazard is 5 percent to 14 percent of the total assessed property value (Impact Factor = 2)
  - Low—Estimated loss from the hazard is 4 percent or less of the total assessed property value (Impact Factor = 1)
  - No impact—No loss is estimated from the hazard (Impact Factor = 0)

The impacts of each hazard category were assigned a weighting factor to reflect the significance of the impact. These weighting factors are consistent with those typically used for measuring the benefits of hazard mitigation actions: impact on people was given a weighting factor of 3; impact on property was given a weighting factor of 2; and impact on the economy was given a weighting factor of 1.

Table 19 -98, Table 19 -99 and Table 19 -100 summarize the impacts for each hazard.

TABLE 19-98.
IMPACT ON PEOPLE FROM HAZARDS

Hazard Event	Impact (high, medium, low)	Impact Factor	Multiplied by Weighting Factor (3)
Avalanche	Low	1	(1x3) = 3
Dam Failure	Low	1	(1x3) = 3
Earthquake	High	3	(3x3) = 9
Flood	Low	1	(1x3) = 3
Landslide	Low	1	(1x3) = 3
Severe Weather	High	3	(3x3) = 9
Severe Winter Weather	High	3	(3x3) = 9
Tsunami	Low	1	(1x3) = 3
Volcano	Low	1	(1x3) = 3
Wildfire	Low	1	(1x3) = 3

TABLE 19-99.
IMPACT ON PROPERTY FROM HAZARDS

Hazard Event	Impact (high, medium, low)	Impact Factor	Multiplied by Weighting Factor (2)
Avalanche	None	0	(0x2) = 0
Dam Failure	Medium	2	(2x2) = 4
Earthquake	High	3	(3x2) = 6
Flood	Low	1	(1x2) = 1
Landslide	Low	1	(1x2) = 2
Severe Weather	High	3	(3x2) = 6
Severe Winter Weather	High	3	(3x2) = 6
Tsunami	Low	1	(1x2) = 2
Volcano	Low	1	(1x2) = 2
Wildfire	Low	1	(1x2) = 2

TABLE 19-100.
IMPACT ON ECONOMY FROM HAZARDS

Hazard Event	Impact (high, medium, low)	Impact Factor	Multiplied by Weighting Factor (1)
Avalanche	None	0	(0x1) = 0
Dam Failure	Medium	2	(2x1) = 2
Earthquake	Medium	2	(2x1) = 2
Flood	Low	1	(1x1) = 1
Landslide	Low	1	(1x1) = 1
Severe Weather	Low	1	(1x1) = 1
Severe Winter Weather	Low	1	(1x1) = 1
Tsunami	Low	1	(1x1) = 1
Volcano	Medium	2	(2x1) = 2
Wildfire	Low	1	(1x1) = 1

19.1.3 Risk Rating and Ranking

The risk rating for each hazard was determined by multiplying the probability factor by the sum of the weighted impact factors for people, property and operations, as summarized in Table 19 -101. Based on these ratings, a priority of high, medium or low was assigned to each hazard. The hazards ranked as being of highest concern are earthquake, severe weather and severe winter weather. Hazards ranked as being of medium concern are landslide, flood and wildfire. The hazards ranked as being of lowest concern are avalanche, dam failure, tsunami and volcano. Table 19 -102 shows the hazard risk ranking.

TABLE 19-101.
HAZARD RISK RATING

Hazard Event	Probability Factor	Sum of Weighted Impact Factors	Total (Probability x Impact)
Avalanche	3	(3+0+0) = 3	(3x3) = 9
Dam Failure	1	(3+4+2) = 9	(1x9) = 9
Earthquake	3	(9+6+2) = 17	(3x17) = 51
Flood	3	(3+2+1) = 6	(3x6) = 18
Landslide	3	(3+2+1) = 6	(3x6) = 18
Severe Weather	3	(9+6+1) = 16	(3x16) =48
Severe Winter Weather	3	(9+6+1) = 16	(3x16) =48
Tsunami	1	(3+2+1) = 6	(1x6) = 6
Volcano	1	(3+2+1) = 7	(1x7) = 7
Wildfire	2	(3+2+1) = 6	(2x6) = 12

**TABLE 19-102.
HAZARD RISK RANKING**

Hazard Ranking	Hazard Event	Category
1	Earthquake	High
2	Severe Weather	High
3	Severe Winter Weather	High
4	Flood	Medium
5	Landslide	Medium
6	Wildfire	Medium
7	Dam Failure	Low
8	Avalanche	Low
9	Volcano	Low
10	Tsunami	Low

PART 3— MITIGATION STRATEGY

CHAPTER 20.

MITIGATION ALTERNATIVES

Catalogs of hazard mitigation alternatives were developed that present a broad range of alternatives to be considered for use in the planning area, in compliance with 44 CFR (Section 201.6(c)(3)(ii)). One catalog was developed for each hazard of concern evaluated in this plan. The catalogs for each hazard are listed in Table 20 -103 through Table 20 -110. The catalogs present alternatives that are categorized in two ways:

- By what the alternative would do:
  - Manipulate a hazard
  - Reduce exposure to a hazard
  - Reduce vulnerability to a hazard
  - Increase the ability to respond to or be prepared for a hazard
- By who would have responsibility for implementation:
  - Individuals
  - Businesses
  - Government.

Hazard mitigation initiatives recommended in this plan were selected from among the alternatives presented in the catalogs. The catalogs provide a baseline of mitigation alternatives that are backed by a planning process, are consistent with the planning partners' goals and objectives, and are within the capabilities of the partners to implement. Some of these actions may not be feasible based on the selection criteria identified for this plan. The purpose of the catalog was to equip the planning partners with a list of what could be considered to reduce risk of the flood hazard within the planning area. All actions identified in Volume 2 of this plan were selected based on the selection criteria described in Chapter 1 of Volume 2. Initiatives in the catalog that are not included for the partnership's action plan were not selected for one or more of the following reasons:

- The action is not feasible.
- The action is already being implemented.
- There is an apparently more cost-effective alternative.
- The action does not have public or political support.

No actions were reviewed for the avalanche hazard other than public education actions, since there is very little development exposed to this hazard within the planning area.

TABLE 20-103.
CATALOG OF MITIGATION ALTERNATIVES—DAM FAILURE

Personal Scale	Corporate Scale	Government Scale
Manipulate Hazard		
• None	1. Remove dams 2. Remove levees 3. Harden dams	1. Remove dams 2. Remove levees 3. Harden dams
Reduce Exposure		
• Relocate out of dam failure inundation areas.	• Replace earthen dams with hardened structures	1. Replace earthen dams with hardened structures 2. Relocate critical facilities out of dam failure inundation areas. 3. Consider open space land use in designated dam failure inundation areas.
Reduce Vulnerability		
• Elevate home to appropriate levels.	• Flood-proof facilities within dam failure inundation areas	1. Adopt higher regulatory floodplain standards in mapped dam failure inundation areas. 2. Retrofit critical facilities within dam failure inundation areas.
Increase Preparation or Response Capability		
1. Learn about risk reduction for the dam failure hazard. 2. Learn the evacuation routes for a dam failure event. 3. Educate yourself on early warning systems and the dissemination of warnings.	1. Educate employees on the probable impacts of a dam failure. 2. Develop a continuity of operations plan.	1. Map dam failure inundation areas. 2. Enhance emergency operations plan to include a dam failure component. 3. Institute monthly communications checks with dam operators. 4. Inform the public on risk reduction techniques 5. Adopt real-estate disclosure requirements for the re-sale of property located within dam failure inundation areas. 6. Consider the probable impacts of climate in assessing the risk associated with the dam failure hazard. 7. Establish early warning capability downstream of listed high hazard dams. 8. Consider the residual risk associated with protection provided by dams in future land use decisions.

TABLE 20-104.
CATALOG OF MITIGATION ALTERNATIVES—EARTHQUAKE

Personal Scale	Corporate Scale	Government Scale
Manipulate Hazard		
None	None	None
Reduce Exposure		
• Locate outside of hazard area (off soft soils)	• Locate or relocate mission-critical functions outside hazard area where possible	• Locate critical facilities or functions outside hazard area where possible
Reduce Vulnerability		
1. Retrofit structure (anchor house structure to foundation) 2. Secure household items that can cause injury or damage (such as water heaters, bookcases, and other appliances) 3. Build to higher design	1. Build redundancy for critical functions and facilities 2. Retrofit critical buildings and areas housing mission-critical functions	1. Harden infrastructure 2. Provide redundancy for critical functions 3. Adopt higher regulatory standards
Increase Preparation or Response Capability		
1. Practice "drop, cover, and hold" 2. Develop household mitigation plan, such as creating a retrofit savings account, communication capability with outside, 72-hour self-sufficiency during an event 3. Keep cash reserves for reconstruction 4. Become informed on the hazard and risk reduction alternatives available. 5. Develop a post-disaster action plan for your household	1. Adopt higher standard for new construction; consider "performance-based design" when building new structures 2. Keep cash reserves for reconstruction 3. Inform your employees on the possible impacts of earthquake and how to deal with them at your work facility. 4. Develop a continuity of operations plan	1. Provide better hazard maps 2. Provide technical information and guidance 3. Enact tools to help manage development in hazard areas (e.g., tax incentives, information) 4. Include retrofitting and replacement of critical system elements in capital improvement plan 5. Develop strategy to take advantage of post-disaster opportunities 6. Warehouse critical infrastructure components such as pipe, power line, and road repair materials 7. Develop and adopt a continuity of operations plan 8. Initiate triggers guiding improvements (such as <50% substantial damage or improvements) 9. Further enhance seismic risk assessment to target high hazard buildings for mitigation opportunities. 10. Develop a post-disaster action plan that includes grant funding and debris removal components.

**TABLE 20-105.
CATALOG OF MITIGATION ALTERNATIVES—FLOOD**

Personal Scale	Corporate Scale	Government Scale
Manipulate Hazard		
1. Clear stormwater drains and culverts 2. Institute low-impact development techniques on property	1. Clear stormwater drains and culverts 2. Institute low-impact development techniques on property	1. Maintain drainage system 2. Institute low-impact development techniques on property 3. Dredging, levee construction, and providing regional retention areas 4. Structural flood control, levees, channelization, or revetments. 5. Stormwater management regulations and master planning 6. Acquire vacant land or promote open space uses in developing watersheds to control increases in runoff
Reduce Exposure		
1. Locate outside of hazard area 2. Elevate utilities above base flood elevation 3. Institute low impact development techniques on property	1. Locate business critical facilities or functions outside hazard area 2. Institute low impact development techniques on property	1. Locate or relocate critical facilities outside of hazard area 2. Acquire or relocate identified repetitive loss properties 3. Promote open space uses in identified high hazard areas via techniques such as: planned unit developments, easements, setbacks, greenways, sensitive area tracks. 4. Adopt land development criteria such as planned unit developments, density transfers, clustering 5. Institute low impact development techniques on property 6. Acquire vacant land or promote open space uses in developing watersheds to control increases in runoff
Reduce Vulnerability		
1. Retrofit structures (elevate structures above base flood elevation) 2. Elevate items within house above base flood elevation 3. Build new homes above base flood elevation 4. Flood-proof existing structures	1. Build redundancy for critical functions or retrofit critical buildings 2. Provide flood-proofing measures when new critical infrastructure must be located in floodplains	1. Harden infrastructure, bridge replacement program 2. Provide redundancy for critical functions and infrastructure 3 Adopt appropriate regulatory standards, such as: increased freeboard standards, cumulative substantial improvement or damage, lower substantial damage threshold; compensatory storage, non-conversion deed restrictions. 4. Stormwater management regulations and master planning. 5. Adopt “no-adverse impact” floodplain management policies that strive to not increase the flood risk on downstream communities.

TABLE 20-105.
CATALOG OF MITIGATION ALTERNATIVES—FLOOD

Personal Scale	Corporate Scale	Government Scale
Increase Preparation or Response Capability		
1. Buy flood insurance 2. Develop household mitigation plan, such as retrofit savings, communication capability with outside, 72-hour self-sufficiency during and after an event	1. Keep cash reserves for reconstruction 2. Support and implement hazard disclosure for the sale/re-sale of property in identified risk zones. 3. Solicit cost-sharing through partnerships with other stakeholders on projects with multiple benefits.	1. Produce better hazard maps 2. Provide technical information and guidance 3. Enact tools to help manage development in hazard areas (stronger controls, tax incentives, and information) 4. Incorporate retrofitting or replacement of critical system elements in capital improvement plan 5. Develop strategy to take advantage of post-disaster opportunities 6. Warehouse critical infrastructure components 7. Develop and adopt a continuity of operations plan 8. Consider participation in the Community Rating System 9. Maintain existing data and gather new data needed to define risks and vulnerability 10. Train emergency responders 11. Create a building and elevation inventory of structures in the floodplain 12. Develop and implement a public information strategy 13. Charge a hazard mitigation fee 14. Integrate floodplain management policies into other planning mechanisms within the planning area. 15. Consider the probable impacts of climate change on the risk associated with the flood hazard 16. Consider the residual risk associated with structural flood control in future land use decisions 17. Enforce National Flood Insurance Program 18. Adopt a Stormwater Management Master Plan

TABLE 20-106.
CATALOG OF MITIGATION ALTERNATIVES—LANDSLIDE

Personal Scale	Corporate Scale	Government Scale
Manipulate Hazard		
1. Stabilize slope (dewater, armor toe) 2. Reduce weight on top of slope 3. Minimize vegetation removal and the addition of impervious surfaces.	1. Stabilize slope (dewater, armor toe) 2. Reduce weight on top of slope	1. Stabilize slope (dewater, armor toe) 2. Reduce weight on top of slope
Reduce Exposure		
• Locate structures outside of hazard area (off unstable land and away from slide-run out area)	• Locate structures outside of hazard area (off unstable land and away from slide-run out area)	1. Acquire properties in high-risk landslide areas. 2. Adopt land use policies that prohibit the placement of habitable structures in high-risk landslide areas.
Reduce Vulnerability		
• Retrofit home.	• Retrofit at-risk facilities.	1. Adopt higher regulatory standards for new development within unstable slope areas. 2. Armor/retrofit critical infrastructure against the impact of landslides.
Increase Preparation or Response Capability		
1. Institute warning system, and develop evacuation plan 2. Keep cash reserves for reconstruction 3. Educate yourself on risk reduction techniques for landslide hazards.	1. Institute warning system, and develop evacuation plan 2. Keep cash reserves for reconstruction 3. Develop a continuity of operations plan 4. Educate employees on the potential exposure to landslide hazards and emergency response protocol.	1. Produce better hazard maps 2. Provide technical information and guidance 3. Enact tools to help manage development in hazard areas: better land controls, tax incentives, information 4. Develop strategy to take advantage of post-disaster opportunities 5. Warehouse critical infrastructure components 6. Develop and adopt a continuity of operations plan 7. Educate the public on the landslide hazard and appropriate risk reduction alternatives.

TABLE 20-107.
CATALOG OF MITIGATION ALTERNATIVES—SEVERE WEATHER AND SEVERE WINTER WEATHER

Personal Scale	Corporate Scale	Government Scale
Manipulate Hazard		
None	None	None
Reduce Exposure		
None	None	None
Reduce Vulnerability		
1. Insulate house 2. Provide redundant heat and power 3. Insulate structure 4. Plant appropriate trees near home and power lines ("Right tree, right place" National Arbor Day Foundation Program)	1. Relocate critical infrastructure (such as power lines) underground 2. Reinforce or relocate critical infrastructure such as power lines to meet performance expectations 3. Install tree wire 4. Ensure air-conditioned facilities for institutionalized vulnerable populations.	1. Harden infrastructure such as locating utilities underground 2. Trim trees back from power lines 3. Designate snow routes and strengthen critical road sections and bridges 4. Provide publicly available cooling centers. 5. Disseminate information on public health impacts of severe weather.
Increase Preparation or Response Capability		
1. Trim or remove trees that could affect power lines 2. Promote 72-hour self-sufficiency 3. Obtain a NOAA weather radio. 4. Obtain an emergency generator.	1. Trim or remove trees that could affect power lines 2. Create redundancy 3. Equip facilities with a NOAA weather radio 4. Equip vital facilities with emergency power sources.	1. Support programs such as "Tree Watch" that proactively manage problem areas through use of selective removal of hazardous trees, tree replacement, etc. 2. Establish and enforce building codes that require all roofs to withstand snow loads 3. Increase communication alternatives 4. Modify land use and environmental regulations to support vegetation management activities that improve reliability in utility corridors. 5. Modify landscape and other ordinances to encourage appropriate planting near overhead power, cable, and phone lines 6. Provide NOAA weather radios to the public. 7. Develop an extreme heat program.

**TABLE 20-108.
CATALOG OF MITIGATION ALTERNATIVES—TSUNAMI**

Personal Scale	Corporate Scale	Government Scale
Manipulate Hazard		
• None	• None	• Build wave abatement structures (e.g. the “Jacks” looking structure designed by the Japanese)
Reduce Exposure		
• Locate outside of hazard area	• Locate structure or mission critical functions outside of hazard area whenever possible.	1. Locate structure or functions outside of hazard area whenever possible. 2. Harden infrastructure for tsunami impacts. 3. Relocate identified critical facilities located in tsunami high hazard areas.
Reduce Vulnerability		
• Apply personal property mitigation techniques to your home such as anchoring your foundation and foundation openings to allow flow though.	• Mitigate personal property for the impacts of tsunami	1. Adopt higher regulatory standards that will provide higher levels of protection to structures built in a tsunami inundation area. 2. Utilize tsunami mapping once available, to guide development away from high risk areas through land use planning.
Increase Preparation or Response Capability		
1. Develop and practice a household evacuation plan. 2. Support/participate in the Redwood Coast Tsunami Working Group. 3. Educate yourself on the risk exposure from the tsunami hazard and ways to minimize that risk.	1. Develop and practice a corporate evacuation plan. 2. Support/participate in the Redwood Coast Tsunami Working Group. 3. Educate employees on the risk exposure from the tsunami hazard and ways to minimize that risk.	1. Create a probabilistic tsunami map for the planning area. 2. Provide incentives to guide development away from hazard areas. 3. Develop a tsunami warning and response system. 4. Provide residents with tsunami inundation maps 5. Join NOAA’s Tsunami Ready program 6. Develop and communicate evacuation routes 7. Enhance the public information program to include risk reduction options for the tsunami hazard

TABLE 20-109.
CATALOG OF MITIGATION ALTERNATIVES—VOLCANO

Personal Scale	Corporate Scale	Government Scale
Manipulate Hazard		
None	None	Limited success has been experienced with lava flow diversion structures
Reduce Exposure		
Relocate outside of hazard area, such as lahar zones	• Locate mission critical functions outside of hazard area, such as lahar zones whenever possible.	Locate critical facilities and functions outside of hazard area, such as lahar zones, whenever possible.
Reduce Vulnerability		
None	• Protect corporate critical facilities and infrastructure from potential impacts of severe ash fall (air filtration capability)	• Protect critical facilities from potential problems associated with ash fall. • Build redundancy for critical facilities and functions.
Increase Preparation or Response Capability		
• Develop and practice a household evacuation plan.	1. Develop and practice a corporate evacuation plan 2. Inform employees through corporate sponsored outreach 3. Develop a cooperative	1. Public outreach, awareness. 2. Tap into state volcano warning system to provide early warning to residents of potential ash fall problems

TABLE 20-110.
CATALOG OF MITIGATION ALTERNATIVES—WILDFIRE

Personal Scale	Corporate Scale	Government Scale
Manipulate Hazard		
• Clear potential fuels on property such as dry overgrown underbrush and diseased trees	• Clear potential fuels on property such as dry underbrush and diseased trees	1. Clear potential fuels on property such as dry underbrush and diseased trees 2. Implement best management practices on public lands.
Reduce Exposure		
1. Create and maintain defensible space around structures 2. Locate outside of hazard area 3. Mow regularly	1. Create and maintain defensible space around structures and infrastructure 2. Locate outside of hazard area	1. Create and maintain defensible space around structures and infrastructure 2. Locate outside of hazard area 3. Enhance building code to include use of fire resistant materials in high hazard area.
Reduce Vulnerability		
1. Create and maintain defensible space around structures and provide water on site 2. Use fire-retardant building materials 3. Create defensible spaces around home	1. Create and maintain defensible space around structures and infrastructure and provide water on site 2. Use fire-retardant building materials 3. Use fire-resistant plantings in buffer areas of high wildfire threat.	1. Create and maintain defensible space around structures and infrastructure 2. Use fire-retardant building materials 3. Use fire-resistant plantings in buffer areas of high wildfire threat. 4. Consider higher regulatory standards (such as Class A roofing) 5. Establish biomass reclamation initiatives
Increase Preparation or Response Capability		
1. Employ techniques from the National Fire Protection Association's Firewise Communities program to safeguard home 2. Identify alternative water supplies for fire fighting 3. Install/replace roofing material with non-combustible roofing materials.	1. Support Firewise community initiatives. 2. Create /establish stored water supplies to be utilized for firefighting.	1. More public outreach and education efforts, including an active Firewise program 2. Possible weapons of mass destruction funds available to enhance fire capability in high-risk areas 3. Identify fire response and alternative evacuation routes 4. Seek alternative water supplies 5. Become a Firewise community 6. Use academia to study impacts/solutions to wildfire risk 7. Establish/maintain mutual aid agreements between fire service agencies. 8. Create/implement fire plans 9. Consider the probable impacts of climate change on the risk associated with the wildfire hazard in future land use decisions

CHAPTER 21.

AREA-WIDE MITIGATION ACTIONS AND IMPLEMENTATION

21.1 SELECTED COUNTY-WIDE MITIGATION ACTIONS

The planning partners and the Steering Committee determined that some initiatives from the mitigation catalogs could be implemented to provide hazard mitigation benefits countywide. Table 21 -111 lists the recommended countywide initiatives, the lead agency for each, and the proposed timeline.

TABLE 21-111.
ACTION PLAN—COUNTYWIDE MITIGATION ACTIONS

Hazards Addressed	Lead Agency	Possible Funding Sources or Resources	Timeline	Objectives
CW-1—Continue to participate in and support the "Resilient King County" initiative.				
All hazards	King County Office of Emergency Management (OEM)	Local, possible grant funding (FEMA, DHS)	Ongoing	1, 3, 4, 7, 13, 14, 15
CW-2—Continue to maintain a website that will house the regional hazard mitigation plan, its progress reports and all components of the plan's maintenance strategy to provide the planning partners and public ongoing access to the plan and its implementation.				
All Hazards	King County OEM	King County OEM operating budget	Ongoing	4, 6, 7, 11, 15
CW-3—Continue to leverage/support/enhance ongoing, regional public education and awareness programs (such as "Take Winter by Storm and "Make it Through") as a method to educate the public on risk, risk reduction and community resilience.				
All Hazards	King County and all planning partners	Local	Ongoing	4, 6, 7, 11, 13, 14, 15
CW-4—Continue to support the use, development and enhancement of a regional alert and notification system.				
All Hazards	King County OEM	Local, possible grant funding (FEMA, DHS, NWS, NOAA)	Ongoing	3, 4, 7, 13
CW-5—Strive to capture time-sensitive, perishable data—such as high water marks, extent and location of hazard, and loss information—following hazard events to support future updates to the risk assessment.				
All hazards	All Planning partners	Local, FEMA (PA)	Short-term	4, 7
CW-6—Encourage signatories for the regional coordination framework for disasters and planned events.				
All Hazards	King County OEM	Local	Ongoing	3, 7, 13, 14
CW-7—Continue ongoing communication and coordination in the implementation of the King County Regional Hazard Mitigation Plan and the 2013 King County Flood Hazard Management Plan.				
Flood	King County OEM, King County Department of Natural Resources & Parks, King County Flood Control District	Local	Ongoing	2, 4, 5, 7, 10, 12

The timeline options shown in Table 21 -111 are defined as follows:

- Short Term = to be completed in 1 to 5 years
- Ongoing = currently being funded and implemented under existing programs.

21.2 BENEFIT/COST REVIEW

The action plan must be prioritized according to a benefit/cost analysis of the proposed projects and their associated costs (44 CFR, Section 201.6(c)(3)(iii)). The benefits of proposed projects were weighed against estimated costs as part of the project prioritization process. The benefit/cost analysis was not of the detailed variety required by FEMA for project grant eligibility under the Hazard Mitigation Grant Program (HMGP) and Pre-Disaster Mitigation (PDM) grant program. A less formal approach was used because some projects may not be implemented for up to 10 years, and associated costs and benefits could change dramatically in that time. Therefore, a review of the apparent benefits versus the apparent cost of each project was performed. Parameters were established for assigning subjective ratings (high, medium, and low) to the costs and benefits of these projects.

Cost ratings were defined as follows:

- **High**—Existing funding will not cover the cost of the project; implementation would require new revenue through an alternative source (for example, bonds, grants, and fee increases).
- **Medium**—The project could be implemented with existing funding but would require a re-apportionment of the budget or a budget amendment, or the cost of the project would have to be spread over multiple years.
- **Low**—The project could be funded under the existing budget. The project is part of or can be part of an ongoing existing program.

Benefit ratings were defined as follows:

- **High—**Project will provide an immediate reduction of risk exposure for life and property.
- **Medium—**Project will have a long-term impact on the reduction of risk exposure for life and property, or project will provide an immediate reduction in the risk exposure for property.
- **Low—**Long-term benefits of the project are difficult to quantify in the short term.

Using this approach, projects with positive benefit versus cost ratios (such as high over high, high over medium, medium over low, etc.) are considered cost-beneficial and are prioritized accordingly.

For many of the strategies identified in this action plan, the partners may seek financial assistance under the HMGP or PDM programs, both of which require detailed benefit/cost analyses. These analyses will be performed on projects at the time of application using the FEMA benefit-cost model. For projects not seeking financial assistance from grant programs that require detailed analysis, the partners reserve the right to define “benefits” according to parameters that meet the goals and objectives of this plan.

21.3 COUNTY-WIDE ACTION PLAN PRIORITIZATION

Table 21 -112 lists the priority of each countywide initiative, using the same parameters used by each of the planning partners in selecting their initiatives. A qualitative benefit-cost review was performed for each of these initiatives.

**TABLE 21-112.
PRIORITIZATION OF COUNTYWIDE MITIGATION ACTIONS**

Initiative #	# of Objectives Met	Benefits	Costs	Do Benefits equal or exceed Costs?	Is project Grant eligible?	Can Project be funded under existing programs/ budgets?	Priority (High, Med., Low)
CW-1	7	High	Medium	Yes	Yes	Yes	High
CW-2	5	Medium	Low	Yes	No	Yes	High
CW-3	7	High	Medium	Yes	Yes	Yes	High
CW-4	4	High	High	Yes	Yes	Yes	High
CW-5	2	Medium	Medium	Yes	Yes	Yes	High
CW-6	4	Medium	Low	Yes	No	Yes	High
CW-7	6	High	High	Yes	Yes	Yes	High

The priorities are defined as follows:

- **High Priority**—A project that meets multiple objectives (i.e., multiple hazards), has benefits that exceed cost, has funding secured or is an ongoing project and meets eligibility requirements for the HMGP or PDM grant program. High priority projects can be completed in the short term (1 to 5 years).
- **Medium Priority**—A project that meets goals and objectives, that has benefits that exceed costs, and for which funding has not been secured but that is grant eligible under HMGP, PDM or other grant programs. Project can be completed in the short term, once funding is secured. Medium priority projects will become high priority projects once funding is secured.
- **Low Priority**—A project that will mitigate the risk of a hazard, that has benefits that do not exceed the costs or are difficult to quantify, for which funding has not been secured, that is not eligible for HMGP or PDM grant funding, and for which the time line for completion is long term (1 to 10 years). Low priority projects may be eligible for other sources of grant funding from other programs.

21.4 PLAN ADOPTION

A hazard mitigation plan must document that it has been formally adopted by the governing body of the jurisdiction requesting federal approval of the plan (44 CFR Section 201.6(c)(5)). For multi-jurisdictional plans, each jurisdiction requesting approval must document that is has been formally adopted. This plan will be submitted for a pre-adoption review prior to adoption to Washington State Emergency Management Division (EMD) and FEMA's Community Rating System contractor, the Insurance Services Office (ISO). Once pre-adoption approval has been provided, all planning partners will formally adopt the plan. All partners understand that DMA compliance and its benefits cannot be achieved until the plan is adopted. Copies of the resolutions adopting this plan for all planning partners can be found in Appendix F of this volume.

21.5 PLAN MAINTENANCE STRATEGY

A hazard mitigation plan must present a plan maintenance process that includes the following (44 CFR Section 201.6(c)(4)):

- A section describing the method and schedule of monitoring, evaluating, and updating the mitigation plan over a 5-year cycle
- A process by which local governments incorporate the requirements of the mitigation plan into other planning mechanisms, such as comprehensive or capital improvement plans, when appropriate
- A discussion on how the community will continue public participation in the plan maintenance process.

This chapter details the formal process that will ensure that the King County Hazard Mitigation Plan remains an active and relevant document and that the planning partners maintain their eligibility for applicable funding sources. The plan maintenance process includes a schedule for monitoring and evaluating the plan annually and producing an updated plan every five years. This chapter also describes how public participation will be integrated throughout the plan maintenance and implementation process. It also explains how the mitigation strategies outlined in this plan will be incorporated into existing planning mechanisms and programs, such as comprehensive land-use planning processes, capital improvement planning, and building code enforcement and implementation. The Plan's format allows sections to be reviewed and updated when new data become available, resulting in a plan that will remain current and relevant.

21.5.1 Plan Implementation

The effectiveness of the hazard mitigation plan depends on its implementation and incorporation of its action items into partner jurisdictions' existing plans, policies and programs. Together, the action items in the plan provide a framework for activities that the Partnership can implement over the next 5 years. The planning team and the Steering Committee have established goals and objectives and have prioritized mitigation actions that will be implemented through existing plans, policies, and programs.

King County Office of Emergency Management (OEM) will have lead responsibility for overseeing the plan implementation and maintenance strategy. Plan implementation and evaluation will be a shared responsibility among all planning partnership members and agencies identified as lead agencies in the mitigation action plans (see planning partner annexes in Volume 2 of this plan). The principle point of contact for this role is:

Janice Rahman
Emergency Management Program Manager
Hazard Mitigation | Mass Care | LEAN | Recovery
3511 NE 2nd St
Renton, WA 98056
(206) 205-4061
Janice.Rahman@Kingcounty.gov

21.5.2 Steering Committee

The Steering Committee is a total volunteer body that oversaw the development of the plan and made recommendations on key elements of the plan, including the maintenance strategy. It was the Steering Committee's position that an oversight committee with representation similar to the initial Steering Committee should have an active role in the plan maintenance strategy. Therefore, it is recommended that a steering committee remain a viable body involved in key elements of the plan maintenance strategy. The new steering committee should strive to include representation from the planning partners, as well as other stakeholders in the planning area.

The steering committee will convene to perform annual reviews at a place and time to be determined. The make-up of this committee can be dynamic, which will allow differing views to have a say in the implementation of the plan. OEM will strive for true "stakeholder" representation on this committee. Individuals involved in this plan update process will be contacted and given the option to remain involved in the process.

21.5.3 Annual Progress Report

The minimum task of the new steering committee will be the evaluation of the progress of the plan. This review will include the following:

- Summary of any hazard events that occurred during the prior year and their impact on the planning area
- Review of successful mitigation actions identified in the plan
- Brief discussion about why targeted strategies were not completed
- Re-evaluation of the action plans to determine if the timeline for identified projects needs to be amended (such as changing a long-term project to a short-term project because of funding availability)
- Recommendations for new projects
- Changes in or potential for new funding options (grant opportunities)
- Impact of any other planning programs or initiatives within the partnership that involve hazard mitigation.
- Identification of training needs within the partnership, such as benefit-cost analysis or E-grants
- Grant coordination within the partnership
- A mechanism for data requests from the partnership to OEM.

OEM will assume the responsibility of initiating the annual progress reporting process. OEM will attempt to reach out to the partnership quarterly in order to expedite completion of the final progress report on an annual basis. A template to guide the planning partners in preparing a progress report has been created as part of this planning process (see Appendix G). The plan maintenance steering committee will provide feedback to the planning team on items included in the template. OEM will then prepare a formal annual report on the progress of the plan. This report should be used as follows:

- The reporting period shall cover January to January of each reporting year.
- OEM will strive to facilitate updates to the report quarterly.
- The timeframe for Steering Committee review of the progress report will be August to October of each reporting cycle.
- A final progress report will be produced no later than October 1 of each reporting year.
- The report will be posted on the King County website page dedicated to the hazard mitigation plan.
- The report will be provided to the local media through a press release.
- The report will be provided to all planning partner governing bodies to inform them of the progress of actions implemented during the reporting period.
- For planning partners that participate in the Community Rating System, the report can be provided as part of the CRS annual re-certification package. The CRS requires an annual

recertification to be submitted by October 1 of every calendar year for which the community has not received a formal audit.

Uses of the progress report will be at the discretion of each planning partner. Annual progress reporting is not a requirement specified under 44 CFR. However, it may enhance the planning partnership's opportunities for funding. While failure to implement this component of the plan maintenance strategy will not jeopardize a planning partner's compliance under the DMA, it may jeopardize its opportunity to partner and leverage funding opportunities with the other partners. Each planning partner was informed of these protocols at the beginning of this planning process (in the "Planning Partner Expectations" package provided at the start of the process), and each partner acknowledged these expectations when with submittal of a letter of intent to participate in this process.

21.5.4 Plan Update

Local hazard mitigation plans must be reviewed, revised if appropriate, and resubmitted for approval in order to remain eligible for benefits under the DMA (44 CFR Section 201.6.d.3). The planning partnership intends to update the plan on a five-year cycle from the date of initial plan adoption. This cycle may be accelerated to less than five years based on the following triggers:

- A federal disaster declaration that impacts the King County planning area
- A hazard event that causes loss of life
- A comprehensive update of the King County Comprehensive Plan or participating city's comprehensive plan.

It will not be the intent of the update process to start from scratch and develop a complete new hazard mitigation plan for the King County planning area. Based on needs identified by the planning team, this update will, at a minimum, include the elements below:

- The update process will be convened through the new steering committee.
- The hazard risk assessment will be reviewed and, if necessary, updated using best available information and technologies.
- The action plans will be reviewed and revised to account for any initiatives completed, dropped, or changed and to account for changes in the risk assessment or new partnership policies identified under other planning mechanisms, as appropriate (such as the general plan).
- The draft update will be sent to appropriate agencies and organizations for comment.
- The public will be given an opportunity to comment on the update prior to adoption.
- Planning partnership governing bodies will adopt their portions of the updated plan.

21.5.5 Continuing Public Involvement

The public will continue to be apprised of hazard mitigation plan actions through the regional hazard mitigation plan website, and copies of the annual progress reports will be distributed to the media. Copies of the plan will be available within the King County Library System. A new public involvement strategy will be initiated based on guidance from the Steering Committee each time the plan is updated. This strategy will be based on the needs and capabilities of the partners at the time of the update. At a minimum, this strategy will include the use of local media outlets within the planning area.

21.5.6 Incorporation into Other Planning Mechanisms

The information on hazard, risk, vulnerability and mitigation contained in this plan update is based on the best science and technology currently available. This information can be invaluable in making decisions required through other planning efforts, such as critical areas planning, growth management planning, and capital facilities planning. All partners will use information from this updated plan as the best available science and data on natural hazards impacting King County. The planning partnership chose not to extend the scope of this plan update into land-use-based recommendations because other programs in the planning area already have a primary focus on land use. Information in the updated plan can be used as a tool in other programs, such as the following:

- Critical areas regulation
- Growth management
- Capital improvements
- Shorelines master planning
- Water Resource Inventory Area planning
- Basin planning
- Emergency management planning
- Strategic planning.

As information becomes available from other planning mechanisms that can enhance this plan, that information will be incorporated via the update process.

21.5.7 Grant Coordination Protocol

It is anticipated that upon completion of this plan, there will be interest among the Planning Partners in pursuing grant funding under FEMA hazard mitigation grant programs. Given the competitive nature of these grant programs, coordination among partners will ensure the highest degree of success in seeking grant funding. Access to such grants is often limited due to the amount of funds available or the grant administration protocol of the State of Washington. It is not in the best interest of the partnership to dilute the funding pool with a high volume of applications from within the partnership that have not been fully vetted in a coordinated manner by designated representatives from the partnership. To avoid such potential setbacks and identify needs for resources, the grant coordination protocol described below is proposed for this plan.

Grant Coordination Lead

Grant Coordination for the King County Hazard Mitigation Planning partnership will be led by the King County OEM. The Hazard Mitigation Program Manager will be the lead point of contact at the OEM.

Tracking Grant Funding Opportunities

King County OEM will monitor FEMA and EMD websites to track FEMA hazard mitigation grant funding opportunities. OEM will notify EMD personnel that OEM will act as the lead point of contact on behalf of the King County Partnership to ensure that OEM personnel are added to all mailing lists for notification of grant funding opportunities. Once OEM has become aware of a grant funding opportunity, OEM staff will send an e-mail notification to the designated point of contact for all King County Planning Partners, notifying them of the funding opportunity and the grant application protocol to be followed. Numerous scenarios could arise under different FEMA grant funding programs. OEM will apply due diligence in tracking these opportunities and identifying the best ways to notify planning partners.

Notice of Intent to Participate

It is standard practice for EMD to require a notice of intent to participate as part of its administration of FEMA hazard mitigation grant programs. The notice of intent is a standard format submittal to the state that includes basic information on the proposed project. This information is used by the state to screen projects for eligibility and completeness. These notices of intent usually have a deadline, and must be submitted and approved by EMD in order for a potential applicant to apply. Approval of a notice of intent by EMD does not ensure grant funding. Approval simply means that the proposed project has been reviewed and approved to proceed to the next phase of the grant application process. There is usually a 60- to 90-day notice of intent period administered by EMD.

As part of this grant coordination protocol, OEM will ask that all Planning Partners considering participation in a grant funding opportunity provide a copy of the completed notice of intent to the OEM point of contact after submittal to EMD. The purpose for this is twofold:

- This will support future progress reporting on the plan by enabling OEM staff to be aware of planning partners that are actively pursuing grants and those that are not.
- This will allow OEM to identify the need for support resources and partnering opportunities to ensure the success of each grant application.

The deadline for submittal of notices of intent to OEM will be specified in the transmittal to all Planning Partners notifying them of the funding opportunity. It should be noted that this step in the protocol is a courtesy and is not mandatory. The intent is not to establish a hierarchy in the grant approval process but to identify needs for technical support and leveraging of resource opportunities within the partnership.

Planning partners on the north and south borders of the planning area that cross into neighboring counties are advised to fully coordinate with those counties for projects within that County. Since this plan will provide the grant eligibility for the grant funding, adherence to this grant coordination protocol is requested, even for projects that fall outside of King County.

Application Support

For planning partners in need of technical support in the grant application process, a formal request for assistance shall be transmitted to OEM along with the notice of intent discussed above. OEM is not committing to providing technical support for all future grant applications but is committing to tracking the needs for technical assistance and identifying possible resources to meet those needs. For example, if five planning partners say they need technical assistance on benefit-cost analysis for a specific grant opportunity, OEM could submit a request to the state on behalf of the partners for training on benefit-cost analysis. Or OEM may identify people within the planning partnership who have expertise in a discipline associated with these needs. It is anticipated that as more planning partners are successful in the grant arena, the more resources will become available under this step in the grant coordination protocol.

Grant Application Coordination

Submitting a notice of intent will not commit a community to applying for the grant. Moreover, a notice of intent may not be approved by the state. In the interest of coordinating applications to aid in the success of this plan, OEM asks that each planning partner that submits a grant application notify OEM via e-mail that the planning partner has “received approval of its notice of intent and has submitted an application on (date).” This will allow OEM to track grant activity for progress reporting and to identify future needs for resources. Should any planning partner want a courtesy review of its grant application prior to submittal to EMD, OEM staff will provide this service upon request as long as sufficient notice is given to provide time for the review.

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APPENDIX A. ACRONYMS AND DEFINITIONS

APPENDIX A.
ACRONYMS AND DEFINITIONS

ACRONYMS

ASHRAE—American Society of Heating, Refrigerating, and Air-Conditioning Engineers

CFR—Code of Federal Regulations

cfs—cubic feet per second

CIP—Capital Improvement Plan

CRS—Community Rating System

DHS—Department of Homeland Security

DMA—Disaster Mitigation Act

EMD—Washington Emergency Management Division

EPA—U.S. Environmental Protection Agency

ESA—Endangered Species Act

FBFM—Fire behavior fuel model

FCAAP—Flood Control Assistance Account Program

FEMA—Federal Emergency Management Agency

FERC—Federal Energy Regulatory Commission

FIRM—Flood Insurance Rate Map

GIS—Geographic Information System

Hazus-MH—Hazards, United States-Multi Hazard

HMGP—Hazard Mitigation Grant Program

IBC—International Building Code

IRC—International Residential Code

LiDAR—Light Detection and Ranging

MM—Modified Mercalli Scale

NEHRP—National Earthquake Hazards Reduction Program

NFIP—National Flood Insurance Program

NOAA—National Oceanic and Atmospheric Administration

NWS—National Weather Service

PDM—Pre-Disaster Mitigation Grant Program

PGA—Peak Ground Acceleration

RCW—Revised Code of Washington

SFHA—Special Flood Hazard Area

SHELDUS—Spatial Hazard Events and Losses Database for the US

USGS—U.S. Geological Survey

WUI—Wildland Urban Interface

DEFINITIONS

100-Year Flood: The term “100-year flood” can be misleading. The 100-year flood does not necessarily occur once every 100 years. Rather, it is the flood that has a 1 percent chance of being equaled or exceeded in any given year. Thus, the 100-year flood could occur more than once in a relatively short period of time. The Federal Emergency Management Agency (FEMA) defines it as the 1 percent annual chance flood, which is now the standard definition used by most federal and state agencies and by the National Flood Insurance Program.

Acre-Foot: An acre-foot is the amount of water it takes to cover 1 acre to a depth of 1 foot. This measure is used to describe the quantity of storage in a water reservoir. An acre-foot is a unit of volume. One acre foot equals 7,758 barrels; 325,829 gallons; or 43,560 cubic feet. An average household of four will use approximately 1 acre-foot of water per year.

Asset: An asset is any man-made or natural feature that has value, including, but not limited to, people; buildings; infrastructure, such as bridges, roads, sewers, and water systems; lifelines, such as electricity and communication resources; and environmental, cultural, or recreational features such as parks, wetlands, and landmarks.

Base Flood: The flood having a 1% chance of being equaled or exceeded in any given year, also known as the “100-year” or “1% chance” flood. The base flood is a statistical concept used to ensure that all properties subject to the National Flood Insurance Program are protected to the same degree against flooding.

Basin: A basin is the area within which all surface water—whether from rainfall, snowmelt, springs, or other sources—flows to a single water body or watercourse. The boundary of a river basin is defined by natural topography, such as hills, mountains, and ridges. Basins are also referred to as “watersheds” and “drainage basins.”

Benefit: A benefit is a net project outcome and is usually defined in monetary terms. Benefits may include direct and indirect effects. For the purposes of benefit-cost analysis of proposed mitigation measures, benefits are limited to specific, measurable, risk reduction factors, including reduction in expected property losses (buildings, contents, and functions) and protection of human life.

Benefit/Cost Analysis: A benefit/cost analysis is a systematic, quantitative method of comparing projected benefits to projected costs of a project or policy. It is used as a measure of cost effectiveness.

Building: A building is defined as a structure that is walled and roofed, principally aboveground, and permanently fixed to a site. The term includes manufactured homes on permanent foundations on which the wheels and axles carry no weight.

Capability Assessment: A capability assessment provides a description and analysis of a community’s current capacity to address threats associated with hazards. The assessment includes two components: an inventory of an agency’s mission, programs, and policies, and an analysis of its capacity to carry them

out. A capability assessment is an integral part of the planning process in which a community's actions to reduce losses are identified, reviewed, and analyzed, and the framework for implementation is identified. The following capabilities were reviewed under this assessment:

- Legal and regulatory capability
- Administrative and technical capability
- Fiscal capability

Community Rating System (CRS): The CRS is a voluntary program under the NFIP that rewards participating communities (provides incentives) for exceeding the minimum requirements of the NFIP and completing activities that reduce flood hazard risk by providing flood insurance premium discounts.

Critical Area: An area defined by state or local regulations as deserving special protection because of unique natural features or its value as habitat for a wide range of species of flora and fauna. A sensitive/critical area is usually subject to more restrictive development regulations.

Critical Facility: Facilities and infrastructure that are critical to the health and welfare of the population. These become especially important after any hazard event occurs. For the purposes of this plan, critical facilities include:

- Structures or facilities that produce, use, or store highly volatile, flammable, explosive, toxic and/or water reactive materials;
- Hospitals, nursing homes, and housing likely to contain occupants who may not be sufficiently mobile to avoid death or injury during a hazard event.
- Police stations, fire stations, vehicle and equipment storage facilities, and emergency operations centers that are needed for disaster response before, during, and after hazard events, and
- Public and private utilities, facilities and infrastructure that are vital to maintaining or restoring normal services to areas damaged by hazard events.
- Government facilities.

Cubic Feet per Second (cfs): Discharge or river flow is commonly measured in cfs. One cubic foot is about 7.5 gallons of liquid.

Dam: Any artificial barrier or controlling mechanism that can or does impound 10 acre-feet or more of water.

Dam Failure: Dam failure refers to a partial or complete breach in a dam (or levee) that impacts its integrity. Dam failures occur for a number of reasons, such as flash flooding, inadequate spillway size, mechanical failure of valves or other equipment, freezing and thawing cycles, earthquakes, and intentional destruction.

Debris Avalanche: Volcanoes are prone to debris and mountain rock avalanches that can approach speeds of 100 mph.

Debris Flow: Dense mixtures of water-saturated debris that move down-valley; looking and behaving much like flowing concrete. They form when loose masses of unconsolidated material are saturated, become unstable, and move down slope. The source of water varies but includes rainfall, melting snow or ice, and glacial outburst floods.

Debris Slide: Debris slides consist of unconsolidated rock or soil that has moved rapidly down slope. They occur on slopes greater than 65 percent.

Disaster Mitigation Act of 2000 (DMA); The DMA is Public Law 106-390 and is the latest federal legislation enacted to encourage and promote proactive, pre-disaster planning as a condition of receiving financial assistance under the Robert T. Stafford Act. The DMA emphasizes planning for disasters before they occur. Under the DMA, a pre-disaster hazard mitigation program and new requirements for the national post-disaster hazard mitigation grant program (HMGP) were established.

Drainage Basin: A basin is the area within which all surface water- whether from rainfall, snowmelt, springs or other sources- flows to a single water body or watercourse. The boundary of a river basin is defined by natural topography, such as hills, mountains and ridges. Drainage basins are also referred to as **watersheds** or **basins**.

Drought: Drought is a period of time without substantial rainfall or snowfall from one year to the next. Drought can also be defined as the cumulative impacts of several dry years or a deficiency of precipitation over an extended period of time, which in turn results in water shortages for some activity, group, or environmental function. A hydrological drought is caused by deficiencies in surface and subsurface water supplies. A socioeconomic drought impacts the health, well-being, and quality of life or starts to have an adverse impact on a region. Drought is a normal, recurrent feature of climate and occurs almost everywhere.

Earthquake: An earthquake is defined as a sudden slip on a fault, volcanic or magmatic activity, and sudden stress changes in the earth that result in ground shaking and radiated seismic energy. Earthquakes can last from a few seconds to over 5 minutes, and have been known to occur as a series of tremors over a period of several days. The actual movement of the ground in an earthquake is seldom the direct cause of injury or death. Casualties may result from falling objects and debris as shocks shake, damage, or demolish buildings and other structures.

Exposure: Exposure is defined as the number and dollar value of assets considered to be at risk during the occurrence of a specific hazard.

Extent: The extent is the size of an area affected by a hazard.

Extreme Heat Event/Heat Wave: Summertime weather that is substantially hotter and/or more humid than average for a location at that time of year. Typically a heat wave lasts two or more days.

Fire Behavior: Fire behavior refers to the physical characteristics of a fire and is a function of the interaction between the fuel characteristics (such as type of vegetation and structures that could burn), topography, and weather. Variables that affect fire behavior include the rate of spread, intensity, fuel consumption, and fire type (such as underbrush versus crown fire).

Fire Frequency: Fire frequency is the broad measure of the rate of fire occurrence in a particular area. An estimate of the areas most likely to burn is based on past fire history or fire rotation in the area, fuel conditions, weather, ignition sources (such as human or lightning), fire suppression response, and other factors.

Flash Flood: A flash flood occurs with little or no warning when water levels rise at an extremely fast rate

Flood Insurance Rate Map (FIRM): FIRMs are the official maps on which the Federal Emergency Management Agency (FEMA) has delineated the Special Flood Hazard Area.

Flood Insurance Study: A report published by the Federal Insurance and Mitigation Administration for a community in conjunction with the community’s Flood Insurance rate Map. The study contains such background data as the base flood discharges and water surface elevations that were used to prepare the FIRM. In most cases, a community FIRM with detailed mapping will have a corresponding flood insurance study.

Floodplain: Any land area susceptible to being inundated by flood waters from any source. A flood insurance rate map identifies most, but not necessarily all, of a community’s floodplain as the Special Flood Hazard Area.

Floodway: Floodways are areas within a floodplain that are reserved for the purpose of conveying flood discharge without increasing the base flood elevation more than 1 foot. Generally speaking, no development is allowed in floodways, as any structures located there would block the flow of floodwaters.

Floodway Fringe: Floodway fringe areas are located in the floodplain but outside of the floodway. Some development is generally allowed in these areas, with a variety of restrictions. On maps that have identified and delineated a floodway, this would be the area beyond the floodway boundary that can be subject to different regulations.

Fog: Fog refers to a cloud (or condensed water droplets) near the ground. Fog forms when air close to the ground can no longer hold all the moisture it contains. Fog occurs either when air is cooled to its dew point or the amount of moisture in the air increases. Heavy fog is particularly hazardous because it can restrict surface visibility. Severe fog incidents can close roads, cause vehicle accidents, cause airport delays, and impair the effectiveness of emergency response. Financial losses associated with transportation delays caused by fog have not been calculated in the United States but are known to be substantial.

Freeboard: Freeboard is the margin of safety added to the base flood elevation.

Frequency: For the purposes of this plan, frequency refers to how often a hazard of specific magnitude, duration, and/or extent is expected to occur on average. Statistically, a hazard with a 100-year frequency is expected to occur about once every 100 years on average and has a 1 percent chance of occurring any given year. Frequency reliability varies depending on the type of hazard considered.

Fujita Scale of Tornado Intensity: Tornado wind speeds are sometimes estimated on the basis of wind speed and damage sustained using the Fujita Scale. The scale rates the intensity or severity of tornado events using numeric values from F0 to F5 based on tornado wind speed and damage. An F0 tornado (wind speed less than 73 miles per hour (mph)) indicates minimal damage (such as broken tree limbs), and an F5 tornado (wind speeds of 261 to 318 mph) indicates severe damage.

Goal: A goal is a general guideline that explains what is to be achieved. Goals are usually broad-based, long-term, policy-type statements and represent global visions. Goals help define the benefits that a plan is trying to achieve. The success of a hazard mitigation plan is measured by the degree to which its goals have been met (that is, by the actual benefits in terms of actual hazard mitigation).

Geographic Information System (GIS): GIS is a computer software application that relates data regarding physical and other features on the earth to a database for mapping and analysis.

Hazard: A hazard is a source of potential danger or adverse condition that could harm people and/or cause property damage.

Hazard Mitigation Grant Program (HMGP): Authorized under Section 202 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act, the HMGP is administered by FEMA and provides grants to states, tribes, and local governments to implement hazard mitigation actions after a major disaster declaration. The purpose of the program is to reduce the loss of life and property due to disasters and to enable mitigation activities to be implemented as a community recovers from a disaster

Hazards U.S. Multi-Hazard (Hazus-MH) Loss Estimation Program: Hazus-MH is a GIS-based program used to support the development of risk assessments as required under the DMA. The Hazus-MH software program assesses risk in a quantitative manner to estimate damages and losses associated with natural hazards. Hazus-MH is FEMA's nationally applicable, standardized methodology and software program and contains modules for estimating potential losses from earthquakes, floods, and wind hazards. Hazus-MH has also been used to assess vulnerability (exposure) for other hazards.

Hydraulics: Hydraulics is the branch of science or engineering that addresses fluids (especially water) in motion in rivers or canals, works and machinery for conducting or raising water, the use of water as a prime mover, and other fluid-related areas.

Hydrology: Hydrology is the analysis of waters of the earth. For example, a flood discharge estimate is developed by conducting a hydrologic study.

Intensity: For the purposes of this plan, intensity refers to the measure of the effects of a hazard.

Inventory: The assets identified in a study region comprise an inventory. Inventories include assets that could be lost when a disaster occurs and community resources are at risk. Assets include people, buildings, transportation, and other valued community resources.

Landslide: Landslides can be described as the sliding movement of masses of loosened rock and soil down a hillside or slope. Fundamentally, slope failures occur when the strength of the soils forming the slope exceeds the pressure, such as weight or saturation, acting upon them.

LiDAR: A remote sensing technology that measures distance by illuminating a target with a laser and analyzing the reflected light.

Lightning: Lightning is an electrical discharge resulting from the buildup of positive and negative charges within a thunderstorm. When the buildup becomes strong enough, lightning appears as a "bolt," usually within or between clouds and the ground. A bolt of lightning instantaneously reaches temperatures approaching 50,000ºF. The rapid heating and cooling of air near lightning causes thunder. Lightning is a major threat during thunderstorms. In the United States, 75 to 100 Americans are struck and killed by lightning each year (see http://www.fema.gov/hazard/thunderstorms/thunder.shtm).

Liquefaction: Liquefaction is the complete failure of soils, occurring when soils lose shear strength and flow horizontally. It is most likely to occur in fine grain sands and silts, which behave like viscous fluids when liquefaction occurs. This situation is extremely hazardous to development on the soils that liquefy, and generally results in extreme property damage and threats to life and safety.

Local Government: Any county, municipality, city, town, township, public authority, school district, special district, intrastate district, council of governments (regardless of whether the council of governments is incorporated as a nonprofit corporation under State law), regional or interstate

government entity, or agency or instrumentality of a local government; any Indian tribe or authorized tribal organization, or Alaska Native village or organization; and any rural community, unincorporated town or village, or other public entity.

Magnitude: Magnitude is the measure of the strength of an earthquake, and is typically measured by the Richter scale. As an estimate of energy, each whole number step in the magnitude scale corresponds to the release of about 31 times more energy than the amount associated with the preceding whole number value.

Mass movement: A collective term for landslides, mudflows, debris flows, sinkholes and lahars.

Mitigation: A preventive action that can be taken in advance of an event that will reduce or eliminate the risk to life or property.

Mitigation Actions: Mitigation actions are specific actions to achieve goals and objectives that minimize the effects from a disaster and reduce the loss of life and property.

Objective: For the purposes of this plan, an objective is defined as a short-term aim that, when combined with other objectives, forms a strategy or course of action to meet a goal. Unlike goals, objectives are specific and measurable.

Peak Ground Acceleration: Peak Ground Acceleration (PGA) is a measure of the highest amplitude of ground shaking that accompanies an earthquake, based on a percentage of the force of gravity.

Preparedness: Preparedness refers to actions that strengthen the capability of government, citizens, and communities to respond to disasters.

Presidential Disaster Declaration: These declarations are typically made for events that cause more damage than state and local governments and resources can handle without federal government assistance. Generally, no specific dollar loss threshold has been established for such declarations. A Presidential Disaster Declaration puts into motion long-term federal recovery programs, some of which are matched by state programs, designed to help disaster victims, businesses, and public entities.

Probability of Occurrence: The probability of occurrence is a statistical measure or estimate of the likelihood that a hazard will occur. This probability is generally based on past hazard events in the area and a forecast of events that could occur in the future. A probability factor based on yearly values of occurrence is used to estimate probability of occurrence.

Repetitive Loss Property: Any NFIP-insured property that, since 1978 and regardless of any changes of ownership during that period, has experienced:

- Four or more paid flood losses in excess of $1000.00; or
- Two paid flood losses in excess of $1000.00 within any 10-year period since 1978 or
- Three or more paid losses that equal or exceed the current value of the insured property.

Return Period (or Mean Return Period): This term refers to the average period of time in years between occurrences of a particular hazard (equal to the inverse of the annual frequency of occurrence).

Riverine: Of or produced by a river. Riverine floodplains have readily identifiable channels. Floodway maps can only be prepared for riverine floodplains.

Risk: Risk is the estimated impact that a hazard would have on people, services, facilities, and structures in a community. Risk measures the likelihood of a hazard occurring and resulting in an adverse condition that causes injury or damage. Risk is often expressed in relative terms such as a high, moderate, or low likelihood of sustaining damage above a particular threshold due to occurrence of a specific type of hazard. Risk also can be expressed in terms of potential monetary losses associated with the intensity of the hazard.

Risk Assessment: Risk assessment is the process of measuring potential loss of life, personal injury, economic injury, and property damage resulting from hazards. This process assesses the vulnerability of people, buildings, and infrastructure to hazards and focuses on (1) hazard identification; (2) impacts of hazards on physical, social, and economic assets; (3) vulnerability identification; and (4) estimates of the cost of damage or costs that could be avoided through mitigation.

Risk Ranking: This ranking serves two purposes, first to describe the probability that a hazard will occur, and second to describe the impact a hazard will have on people, property, and the economy. Risk estimates for the City are based on the methodology that the City used to prepare the risk assessment for this plan. The following equation shows the risk ranking calculation:

Risk Ranking = Probability + Impact (people + property + economy)

Robert T. Stafford Act: The Robert T. Stafford Disaster Relief and Emergency Assistance Act, Public Law 100-107, was signed into law on November 23, 1988. This law amended the Disaster Relief Act of 1974, Public Law 93-288. The Stafford Act is the statutory authority for most federal disaster response activities, especially as they pertain to FEMA and its programs.

Sinkhole: A collapse depression in the ground with no visible outlet. Its drainage is subterranean. It is commonly vertical-sided or funnel-shaped.

Special Flood Hazard Area: The base floodplain delineated on a Flood Insurance Rate Map. The SFHA is mapped as a Zone A in riverine situations and zone V in coastal situations. The SFHA may or may not encompass all of a community's flood problems

Stakeholder: Business leaders, civic groups, academia, non-profit organizations, major employers, managers of critical facilities, farmers, developers, special purpose districts, and others whose actions could impact hazard mitigation.

Stream Bank Erosion: Stream bank erosion is common along rivers, streams and drains where banks have been eroded, sloughed or undercut. However, it is important to remember that a stream is a dynamic and constantly changing system. It is natural for a stream to want to meander, so not all eroding banks are "bad" and in need of repair. Generally, stream bank erosion becomes a problem where development has limited the meandering nature of streams, where streams have been channelized, or where stream bank structures (like bridges, culverts, etc.) are located in places where they can actually cause damage to downstream areas. Stabilizing these areas can help protect watercourses from continued sedimentation, damage to adjacent land uses, control unwanted meander, and improvement of habitat for fish and wildlife.

Steep Slope: Different communities and agencies define it differently, depending on what it is being applied to, but generally a steep slope is a slope in which the percent slope equals or exceeds 25%. For this study, steep slope is defined as slopes greater than 33%.

Sustainable Hazard Mitigation: This concept includes the sound management of natural resources, local economic and social resiliency, and the recognition that hazards and mitigation must be understood in the largest possible social and economic context.

Thunderstorm: A thunderstorm is a storm with lightning and thunder produced by cumulonimbus clouds. Thunderstorms usually produce gusty winds, heavy rains, and sometimes hail. Thunderstorms are usually short in duration (seldom more than 2 hours). Heavy rains associated with thunderstorms can lead to flash flooding during the wet or dry seasons.

Tornado: A tornado is a violently rotating column of air extending between and in contact with a cloud and the surface of the earth. Tornadoes are often (but not always) visible as funnel clouds. On a local scale, tornadoes are the most intense of all atmospheric circulations, and winds can reach destructive speeds of more than 300 mph. A tornado's vortex is typically a few hundred meters in diameter, and damage paths can be up to 1 mile wide and 50 miles long.

Vulnerability: Vulnerability describes how exposed or susceptible an asset is to damage. Vulnerability depends on an asset's construction, contents, and the economic value of its functions. Like indirect damages, the vulnerability of one element of the community is often related to the vulnerability of another. For example, many businesses depend on uninterrupted electrical power. Flooding of an electric substation would affect not only the substation itself but businesses as well. Often, indirect effects can be much more widespread and damaging than direct effects.

Watershed: A watershed is an area that drains downgradient from areas of higher land to areas of lower land to the lowest point, a common drainage basin.

Wildfire: These terms refer to any uncontrolled fire occurring on undeveloped land that requires fire suppression. The potential for wildfire is influenced by three factors: the presence of fuel, topography, and air mass. Fuel can include living and dead vegetation on the ground, along the surface as brush and small trees, and in the air such as tree canopies. Topography includes both slope and elevation. Air mass includes temperature, relative humidity, wind speed and direction, cloud cover, precipitation amount, duration, and the stability of the atmosphere at the time of the fire. Wildfires can be ignited by lightning and, most frequently, by human activity including smoking, campfires, equipment use, and arson.

Windstorm: Windstorms are generally short-duration events involving straight-line winds or gusts exceeding 50 mph. These gusts can produce winds of sufficient strength to cause property damage. Windstorms are especially dangerous in areas with significant tree stands, exposed property, poorly constructed buildings, mobile homes (manufactured housing units), major infrastructure, and aboveground utility lines. A windstorm can topple trees and power lines; cause damage to residential, commercial, critical facilities; and leave tons of debris in its wake.

Zoning Ordinance: The zoning ordinance designates allowable land use and intensities for a local jurisdiction. Zoning ordinances consist of two components: a zoning text and a zoning map.

APPENDIX B.
5-YEAR PROGRESS REPORT ON PREVIOUS PLANS

APPENDIX B.
5-YEAR PROGRESS REPORT ON PREVIOUS PLANS

REPORTING PERIOD

November 2009 through September 2013

BACKGROUND

King County has developed and maintained a regional hazard mitigation plan since 2004, most recently updated in 2009. The King County Regional Hazard Mitigation Plan identifies resources, information, and strategies for reducing risk associated with natural hazards in the county. The plan was adopted by the King County Council in November 2009 and approved by FEMA Region X on December 2, 2009. Several King County cities and special-purpose districts in the county created annexes to link their jurisdictions to the 2009 King County plan. The plan and annexes are available to the public online at the following website:

> http://www.kingcounty.gov/safety/prepare/EmergencyManagementProfessionals/Plans/RegionalHazardMitigationPlan/2009HazardMitigationPlan.aspx

A new update of the regional hazard mitigation plan is underway, with participation by most of the jurisdictions that participated in the 2009 plan, as well as additional municipalities and special districts in the county. The new update will be adopted before the end of 2014. The following jurisdictions participating in the current update either were participants in King County's 2009 regional plan or have their own current adopted hazard mitigation plans:

- City of Auburn
- City of Bothell
- City of Federal Way
- City of Issaquah
- City of Kent (including annex for Kent Fire Department/King County Fire District 37)
- City of Mercer Island
- City of Pacific
- City of Redmond
- City of Renton
- City of Shoreline (including annex for Shoreline Fire Department /King County Fire District 4)
- City of Snoqualmie
- City of Tukwila
- City of Woodinville (an annex to the North King and South Snohomish Counties Regional Mitigation Plan for Natural Hazards)
- Covington Water District
- Highline Water District

- King County Water District 19
- King County Water District 111
- Soos Creek Water District
- Sammamish Plateau Water and Sewer District
- Southwest Suburban Sewer District
- South King Fire and Rescue.

Purpose

This progress report provides an update on implementation of the action plans for all jurisdictions participating in the 2014 regional plan update. It was prepared by the 2014 update planning team and reviewed by the 2014 update steering committee. The objective is to ensure that there is a continuous planning process that keeps the regional hazard mitigation plan responsive to stakeholder needs and capabilities. The contents of this progress report are as follows:

- Summary overview of action plan progress
- Recent natural hazard events
- Changes in risk exposure within the planning area
- Mitigation success stories
- Itemized review of the action plan
- Changes in capability in the planning area that could impact plan implementation
- Recommendations for changes/enhancement.

The Steering Committee

The update steering committee holds an evolving role in plan implementation, based on the hazard mitigation needs of the region. At a minimum, the steering committee provides technical review and oversight on development of implementation progress reports. Table 1 lists current steering committee membership.

SUMMARY OVERVIEW OF ACTION PLAN PROGRESS

The 2009 King County regional hazard mitigation plan, associated jurisdictional annexes, and other previous hazard mitigation plans by participants in the 2014 update all include action plans that identify specific mitigation actions. Table 2 summarizes the number of initiatives in each action plan and current progress as of the time of this progress report.

TABLE 1
2013 STEERING COMMITTEE MEMBERS

Name	Title	Jurisdiction or Agency
Janice Rahman	Emergency Management Program Manager	King County Office of Emergency Management
Barnaby Dow	Emergency Management Program Manager	King County Office of Emergency Management
Bob Freitag	Director of the Institute for Hazard Mitigation Planning and Research	University of Washington
Denis Uhler	Director of Supply Chain Management	Overlake Hospital
Dominic Maranzo	Emergency Manager	City of Kent
Ed Reed	Zone 3 Coordinator	King County
Gail Harris	Emergency Manager	City of Shoreline
James Kraman	Event Manager	Century Link Field
James Tritten	Emergency Preparedness Manager	Valley Medical Center
Kimberly Behymer	Program Coordinator	City of Kent
Lee Gaskill	Police Lieutenant	City of Algona
Mark Chubb	Fire Chief	King County Fire District No. 20
Mike Ryan	Zone 1 Coordinator	King County
Milton Guerreiro	Fire Lieutenant	King County Fire District No. 2 – Burien Fire
Monica Walker	Project/Program Manager	King County Water and Land Resources Division
Rick Wallace	President	Vashon Be Prepared
Robert Taylor	Water Resources Manager	Covington Water District
Sarah Miller	Emergency Preparedness Manager	City of Auburn
Scott Emry	Risk Management Manager	Lake Washington School District

TABLE 2.
SUMMARY OVERVIEW OF ACTION PLAN PROGRESS

Plan	Adoption Date	Total Number of Mitigation Initiatives	Mitigation Initiatives Started or Completed: Number of Initiatives	Mitigation Initiatives Started or Completed: Percent of Total	Mitigation Initiatives Not Started: Number of Initiatives	Mitigation Initiatives Not Started: Percent of Total
2009 King County Regional Plan	November 2009	36	29	81%	7	19%
City of Auburn Annex	February 2013	12	NA	NA	NA	NA
City of Bothell Hazard Mitigation Plan	June 2010	25	19	76%	6	24%
City of Federal Way Annex	February 2010	6	5	83%	1	17%
City of Issaquah Annex	January 2010	5	4	80%	1	20%
City of Kent Local Hazard Mitigation Plan	September 2004	11	6	55%	5	45%
City of Mercer Island Hazard Mitigation Plan Update	December 2010	11	10	91%	1	9%
City of Pacific Annex	July 2009	9	NA	NA	NA	NA
City of Redmond Hazards Mitigation Plan	December 2009	6	6	100%	0	0%
City of Renton Hazard Mitigation Plan	April 2012	50	40	80%	10	20%
City of Shoreline Multijurisdictional Hazard Mitigation Plan Update	November 2009	8	8	100%	0	0%
City of Snoqualmie Hazard Mitigation Plan Update	March 2010	41	NA	NA	NA	NA
City of Tukwila Hazard Mitigation Plan	April 2010	4	4	100%	0	0%
City of Woodinville Annex to North King and South Snohomish Counties Regional Mitigation Plan for Natural Hazards	September 2010	13	9	69%	4	31%
Covington Water District Annex	June 2009	7	6	86%	1	14%
Highline Water District Annex	October 2010	3	3	100%	0	0%
King County Water District 19 Annex	June 2009	3	3	100%	0	0%
King County Water District 111 Hazard Mitigation Plan	December 2009	10	1	11%	9	89%
Sammamish Plateau Water and Sewer District Annex	June 2009	1	1	100%	0	0%

**TABLE 2.
SUMMARY OVERVIEW OF ACTION PLAN PROGRESS**

Plan	Adoption Date	Total Number of Mitigation Initiatives	Mitigation Initiatives Started or Completed: Number of Initiatives	Mitigation Initiatives Started or Completed: Percent of Total	Mitigation Initiatives Not Started: Number of Initiatives	Mitigation Initiatives Not Started: Percent of Total
Soos Creek Water District Hazard Mitigation Plan	February 2010	7	4	57%	3	43%
Southwest Suburban Sewer District Annex	September 2009	5	NA	NA	NA	NA
King County Fire District 4 (Shoreline Fire Department) Annex to City of Shoreline Multijurisdictional Hazard Mitigation Plan Update	July 2009	5	5	100%	0	0%
King County Fire District 37 (Kent Fire Department) Annex to City of Kent Local Hazard Mitigation Plan	September 2004	2	2	100%	0	0%
South King Fire & Rescue Annex	June 2009	3	NA	NA	NA	NA

RECENT NATURAL HAZARD EVENTS IN THE PLANNING AREA

The following hazard events occurred within the planning area during the performance period:

Declared Emergencies:

- **January 11, 2011 (DR-1963) —**Severe winter storm, flooding, landslides and mudslides
  - According to NOAA’S National Climatic Data Center, “A cold easterly wind through the Columbia River Gorge was keeping cold air trapped in the Gorge as a strong Pacific frontal system moved inland. This system spread precipitation over the Gorge starting as snow and changing over to freezing rain as the air mass warmed.” The preliminary damage assessment for the seven counties affected by the storm was estimated at $8.7 million in damages.
- **January 14, 2012 (DR-4056)—**Severe winter storm, flooding, landslides and mudslides
  - According to the National Climatic Data Center, “arctic air moved into the region followed by a series of moderate to strong upper level storm systems riding on a moist subtropical jet stream. The result was widespread heavy snow and local high winds.” The preliminary damage assessment for the 11 counties affected by the storm was estimated at $32 million in damages.

Additionally, the following notable events were recorded in the County between 2010 and 2013 accounting for 6 reported fatalities and an estimated $5.4 million in damages:

- **Avalanche**
  - ***2012 Tunnel Creek***—3 fatalities
  - ***2013 Snoqualmie Pass***—2 fatalities in one day from two separate events
- **Severe Weather**
  - ***June 2010 Funnel cloud in Rainier Valley***—very minor property damage
  - ***December 2010 Heavy Rain***—estimated $3 million in damages
  - ***December 2010 Thunderstorm and Wind***—estimated $25,000 in damages
  - ***January 2011 Heavy Rain***—1 fatality and estimated $20,000 in damages
  - ***July 2012 Lightning***—1 injury and estimated $100,000 in damages
  - ***January 2013 Debris Flow***—estimated $5,000 in damages
  - ***May 2013 Thunderstorm and Wind***—estimated $25,000 in damages
  - ***July 2013 Lightning***—estimated $5,000 in damages
  - ***July 2013 Lightning***—estimated $10,000 in damages
  - ***September 2013 Heavy Rain***—estimated $10,000 in damages
- **Severe Winter Weather**
  - ***January 2011 Winter Weather and Ice Storm***—estimated $2 million in damages
  - ***January 2012 Winter Weather and Ice Storm***—estimated $267,000 in damages
  - ***December 2012 Winter Weather and Heavy Snow***— no reported damage

CHANGES IN RISK EXPOSURE IN THE PLANNING AREA

The population in the planning area has increased 3.8 percent since 2009 to an estimated 1,981,900 people as of April of 2013. Property exposure has also increased during the same time period. The planning area is estimated to have over 565,000 buildings representing over $556 billion in exposed structure and contents.

The 2009 Hazard Mitigation Plan addressed the probable impacts of the following natural hazard events in the planning area:

- Avalanche
- Dams/Dam Safety
- Drought
- Earthquake
- Fire
- Flooding
- Severe Weather
- Landslide
- Tsunami & Seiches.

No natural hazard event occurred in the planning area during the performance period that would alter or change the probability of occurrence or ranking of risk for the natural hazards addressed by the Hazard Mitigation plan; however, the completion of upgrades to the Howard Hanson Dam in the Green River Valley has likely decreased the probability of an event in this area.

REVIEW OF THE ACTION PLAN

This section reviews the action plans and lists the status of each initiative from the hazard mitigation plans, grouped by jurisdiction. The action plan initiative summary in Table 3 provides the following information:

- Brief summary of initiative; note that initiatives from the 2009 King County Regional Hazard Mitigation Plan Update are coded based on responsible County agency, as follows:
  - KCSO = King County Sheriff's Office
  - SWD = Solid Waste Division
  - PH = Public Health
  - ITS = Information and Technology Services
  - MKCT = Metro King County Transit
  - FMD = Facilities Management Division
  - FMO = Fire Marshall's Office
  - DNRP = Department of Natural Resources and Parks
- Indication of whether any action has been taken
- Current timeline
- Indication of whether the project priority has changed
- Status (complete, ongoing or no progress)
- Comments, including the following information:
  - Was any element of the initiative carried out during the reporting period?
  - If no action was completed, why?
  - Is the timeline for implementation for the initiative still appropriate?

If the initiative was completed, does it need to be changed or removed from the action plan?

TABLE 3.
CURRENT PROGRESS ON ACTION PLAN INITIATIVES

Action Taken?	Timeline	Priority Changed?	Comment (Describe progress or changed priority)	Status
2009 King County Regional Plan				
KCSO-1—Enhance homeland security, mitigation, and response capabilities by acquiring dedicated staff for training, planning, response, and intelligence sharing and analysis				
No	Long Term	No	Due to King County General Fund budget deficits, the Sheriff's Office has not been able to enhance its homeland security mission to include both mitigation and response capabilities by acquiring additional staffing. Current staffing levels do not allow for this work to proceed and, in fact, the Sheriff's Office is experiencing staffing shortages at all levels. We attempt to support the mission with limited personnel on an ad hoc basis. Unless FTE funding is supported through the greater King County budget process it is not anticipated that this action will occur in the near to medium term.	No Progress
SWD-1—*Grid 2 & 3 repairs*. Structural seismic retrofit of the Enumclaw transfer station. This initiative sets steel plating to the roof repairs increasing the resistance of the structure to strong earthquakes.				
Yes	Short Term	No	Completed in April 2009	Complete
SWD-2—*Perimeter Wall*. Phase 2 of the structural seismic retrofit to the Enumclaw transfer station. This initiative sets steel plating to the perimeter wall increasing the resistance of the structure to strong earthquakes.				
Yes	Short Term	No	Completed in April 2009	Complete
SWD-3—*Panel to Panel joint connections*. Phase 3 of the structural seismic retrofit to the Enumclaw transfer station. This initiative sets connecting the panels with joint connectors increasing the resistance of the structure to strong earthquakes				
Yes	Short Term	No	Completed in April 2009	Complete
SWD-4—*Roof parapet bracing*. Phase 4 of the structural seismic retrofit to the Enumclaw transfer station. This initiative sets connecting the roof parapet with steel bracing increasing the resistance of the structure to strong earthquakes				
Yes	Short Term	No	Completed in April 2009	Complete
SWD-5—*Sheer wall connections*. Phase 5 of the structural seismic retrofit to the Enumclaw transfer station. This initiative sets sheer wall bracing for increasing the resistance of the structure to strong earthquakes				
Yes	Short Term	No	Completed in April 2009	Complete
PH-1—Support the general public's health and safety by educating Public Health staff in emergency and disaster response				
Yes	Long Term	No	Continually provide orientations and trainings to PH staff serving on emergency response teams.	Ongoing
PH-2—Enhance communication of Public Health sites internally (both within and between PH sites) as well as with other regional agencies through amateur and short-range radio programs				
Yes	Short Term	No	Completed outfitting PH sites with radio capability.	Complete

**TABLE 3.
CURRENT PROGRESS ON ACTION PLAN INITIATIVES**

Action Taken?	Timeline	Priority Changed?	Comment (Describe progress or changed priority)	Status
PH-3—Develop an infectious disease outbreak response team program				
Yes	Long Term	No	Recruiting and training Epis to serve on an outbreak response team.	Ongoing
PH-4—Educate the public in disaster response activities				
Yes	Long Term	No	Provided training and education to community based organizations and healthcare facilities on continuity planning.	Ongoing
PH-5—Support and enhance first responder disaster reporting and regional emergency electronic data collection				
No	Long Term	No	RIMS or common operating procedure for KC to support regional, multidisciplinary reporting.	No Progress
PH-6a—Mitigate structural damage at Public Health sites. This initiative also involves training to determine structural damage during and after hazard events				
No	Long Term	No	Determined to be role of KC FMD, not Public Health	No Progress
PH-6b—Mitigate non-structural damage at Public Health sites. This initiative also involves training to determine non- structural damage during and after hazard events				
No	Long Term	No	Determined to be role of KC FMD, not Public Health	No Progress
PH-7—Enhance syndromic surveillance program to support public health during emergencies and disasters				
Yes	Short Term	No	Incorporated all school districts into surveillance system.	Complete
PH-8—Enhance environmental health response programs for terrorist acts involving chemical and radioactive events, threats to food and water supply and airborne illnesses				
Yes	Long Term	No	Developed environmental health response team.	Ongoing
ITS-1—Provide alternative sites and communication paths for County's information and communication infrastructure. This initiative also seeks to retrofit existing facilities to improve disaster resistance.				
Yes	Long Term	No	KCIT has upgraded the external connections into the King County Wide Area Network (KCWAN) establishing 2 redundant connections at each of the entry points, King County Data Center and at the Seattle location. The redundant connections are provided by two separate Internet Service Providers (ISP) on diverse paths. The King County Firewalls have been upgraded; KCIT has installed 4 redundant firewalls in 2 separate locations. Upgraded all network routers and switches within the KCWAN infrastructure establishing an equipment replacement fund, and schedule to ensure all KCWAN infrastructure remains current and supported by the vendor. KCIT is in the process of replacing the current telecommunications systems and utilizing Voice Over IP technology. KCIT has an established Alternate Data Center designated specifically for Disaster Recovery of essential systems and applications. KCIT is also in the process of establishing additional alternatives for Disaster Recovery by utilizing Virtual and Cloud technology.	Ongoing

**TABLE 3.
CURRENT PROGRESS ON ACTION PLAN INITIATIVES**

Action Taken?	Timeline	Priority Changed?	Comment (Describe progress or changed priority)	Status
MKCT-1—Construct downtown Seattle transit tunnel positive ventilation system to allow for decontamination and recovery following chemical, gas, or fire event.				
Yes	Short Term	No		Complete
MKCT-2—Install security cameras on public buses to deter crime associated with civil unrest and terrorist acts				
Yes	Long Term	No	All new coaches procured will be camera equipped.	Ongoing
FMD-1—Structural seismic retrofit of county buildings to improve resistance to earthquakes				
Yes	Short Term	No	All county buildings that FMD is responsible for have been seismically upgraded.	Complete
FMD-2—Administration Building 401-403 Security Additions. Install motion detector, duress buttons, camera and monitoring system				
Yes	Short Term	No	Added camera and duress	Complete
FMD-3—Administration Building 5th floor - Elections Security Upgrade. Install card access control, duress buttons, camera and video monitoring system				
Yes	Short Term	No	Added camera, readers and duress	Complete
FMD-4—Administration Building 6th floor - Finance Security Upgrade. Install card access control, duress buttons, camera and video monitoring system				
Yes	Short Term	No	Added readers and duress	Complete
FMD-5—Elections 1st Ave MBOS Security Upgrade. Install card access control, duress buttons, camera and video monitoring system				
No	Short Term	Yes	Leased space- No longer occupied by Elections.	No Progress
FMO-1—Continue inspection of existing and new construction				
Yes	Long Term	Yes	New construction permits – no change. Annual inspection permits – priority reduced and some work contracted to local fire districts.	Ongoing
FMO-2—Provide plan reviews for noted construction				
Yes	Long Term	No		Ongoing
FMO-3—Support education, training and information programs				
No	Long Term	No	Ongoing outreach not currently in our business plan. Some information maintained on Department’s website.	No Progress
FMO-4—Work with schools and fire service public educators to deliver public safety messages				
Yes	Long Term	No	Conduct annual fire safety inspection and collect fire drill reports.	Ongoing

TABLE 3.
CURRENT PROGRESS ON ACTION PLAN INITIATIVES

Action Taken?	Timeline	Priority Changed?	Comment (Describe progress or changed priority)	Status
DNRP-1—Snoqualmie 205 (Fund 318F). Cooperative project between King County, City of Snoqualmie and Corps of Engineers to improve flood hazard conditions above Snoqualmie Falls through major channel excavation improvements.				
Yes	Short Term	No	Cooperative project between City of Snoqualmie, King County, and Army Corps of Engineers completed. Monitoring for sediment retention at site.	Complete
DNRP-2—North Bend 205 (Fund 318F and 318U). This project is a cooperative flood damage reduction project between the Corps of Engineers (Corps), King County and the City of North Bend. The project will evaluate cost effective flood reduction options along the South and Middle Fork Snoqualmie Rivers in and around the City.				
No	Long Term	Yes	Feasibility study conducted by U.S. Army Corps of Engineers determines project to be unfeasible. Addressing highest priority needs through implementation of South Fork Levee Improvement Project and the Upper Snoqualmie valley Residential Mitigation Project.	No Progress
DNRP-3—Rivers Major Maintenance (Fund 318F and 318U). Major rivers maintenance project includes funds to repair damaged structural elements of King County's extensive inventory of flood protection facilities.				
Yes	Long Term	No	Ongoing action, implemented annual by King County Water and Land Resources Division and the Flood Control District.	Ongoing
DNRP-4—Floodway Corridor Restoration (FUND 318F and 318U). Floodway corridor restoration projects include the removal, slope-back or setback of County-owned flood protection facilities and other structural features to allow for improved riparian habitat, greater channel diversity and migration, reclaimed flood storage and enhanced open space or recreational/-interpretive uses.				
Yes	Long Term	No	Ongoing action, implemented annual by King County Water and Land Resources Division and the Flood Control District.	Ongoing
DNRP-5—Flood Hazard Mitigation (FUND 318F and 318U). Flood hazard mitigation projects include the acquisition of repetitively damaged homes, purchase of underdeveloped land to prevent future development in flood prone areas, and where cost-effective and feasible, the elevation of residential homes that sustain recurring deep, low- velocity flooding.				
Yes	Long Term	No	Ongoing action implemented annual by the King County Water and Land Resources Division and the Flood Control District.	Ongoing
DNRP-6—Critical Facility Retrofit. Currently, the fuel supply tanks for King County flood facilities cannot withstand a moderate to major quake. This project would retrofit the Black River Pump Station.				
Yes	Short Term	Yes	Construction in progress, June 2013-February 2014. Project is updating fuel pumps to double wall contaminant, the statutory containment, and is designed to meet seismic requirements.	Ongoing
DNRP-7—Critical Facility Relocation. Relocate the Flood Warning Center from its current location that is subject to severe seismic exposure, to a location that is not subject to any natural hazard risk exposure.				
Yes	Short Term	Yes	Moved to King Street Center in 2006	Complete

TABLE 3.
CURRENT PROGRESS ON ACTION PLAN INITIATIVES

Action Taken?	Timeline	Priority Changed?	Comment (Describe progress or changed priority)	Status
DNRP-8—Critical Facility Upgrade. Update the flood warning telemetry and gauging, computers, software applications, emergency power and other response facilities.				
Yes	Ongoing	Yes	Telemetry and gaging in primarily done by USGS through an agreement with King County. Other systems have been improved overtime.	Ongoing
DNRP-9—Flood Hazard Reduction Programs. This initiative includes elements such as hazard identification, warning, information dissemination and public outreach are vital to the mitigation of the natural hazards impacting King County.				
Yes	Long Term	No	Ongoing action, implemented annually by the King County Water and Land Resources Division and the Flood Control District.	Ongoing
City of Auburn Annex				
Retrofit M&O facility to reduce susceptibility to earthquake damage.				
			No progress reported.	
Installation of seismic protection valves on City reservoirs to provide for automatic shutoff in event of an earthquake.				
			No progress reported.	
Upgrade computer server racks throughout City to reduce susceptibility to earthquake damage.				
			No progress reported.	
Purchase and implement software and hardware to comply with the State certification requirements for early destruction of source documents after digitization in compliance with the State of Washington Records Retention laws. This will safeguard records in case of disaster.				
			No progress reported.	
Expand and reconfigure stormwater detention ponds on West Hill along S. 296th St. to reduce wintertime flooding along the valley floor below.				
			No progress reported.	
Prepare and adopt a new optional Comprehensive Plan element for Natural Hazard Reduction.				
			No progress reported.	
Measures to prevent acts of terrorism from occurring at key City facilities (Justice Center, Emergency Operations Center, City Hall, etc.)				
			No progress reported.	
Develop and adopt changes to City Code to limit tree removal within certain sloped or landslide hazard susceptible areas.				
			No progress reported.	
Create part or full-time FTE position to conduct disaster related public education throughout the City.				
			No progress reported.	

TABLE 3.
CURRENT PROGRESS ON ACTION PLAN INITIATIVES

Action Taken?	Timeline	Priority Changed?	Comment (Describe progress or changed priority)	Status
Ability to produce own stats and data capability.				
			No progress reported.	
Create, fund, and administer a grant or low interest loan program that allows homeowners to retrofit single-family homes to protect against earthquakes.				
			No progress reported.	
Conduct community education campaign to addresses pandemic flu issues (See Public Education also).				
			No progress reported.	
City of Bothell Hazard Mitigation Plan				
To provide seismic valves, security barriers and improve notification and response to Morningside Reservoir and Booster Station.				
Yes	Long Term	Yes	Developing a plan to install additional motion sensor alarms and Mach security cameras at other critical facilities/sites.	Ongoing
To rehabilitate City bridges for preservation and maintaining the existing integrity for safe use. Rehabs may include seismic and safety improvements.				
Yes	Long Term	No	Received grant funds to perform seismic retrofits on 195th St. bridge. Anticipated for 2015 construction. 240th Bridge replaced. Seeking funding for Sammamish River Bridge. Minor maintenance & regular inspections ongoing.	Ongoing
Installations of backup power supply and alarm system at Maywood water pump station.				
Yes	Long Term	Yes	In the process of upgrading the SCADA communications for this site (phase 2 of SCADA upgrades)	Ongoing
Will increase lane capacity at the NE 195th St/N Creek Pkwy intersection and will increase the number of westbound lanes from two to three through lanes along the section of NE 195th St between N Creek Pkwy and the I-405 northbound onramp.				
Yes		No		Complete
This project realigns SR 522 one block to the south to create a new streamlined “T” intersection at SR 527. SR 527 and 98th Avenue NE are extended south from Main Street to the new SR 522 realignment. The roadway provides two lanes in each direction with left turn lanes as necessary, sidewalks, intersection improvements, traffic signals, utilities, lighting, and landscaping.				
Yes	Short Term	No	Traffic shifted to new roadway August 12, 2013. Project scheduled to be complete by mid-2014.	Ongoing
Replace the existing bridge on 240th St SE in the North Creek Valley area.				
Yes		No	Project completed in February 2012.	Complete
Construct booster pump station modification equipped with increase capacity and backup pumping facilities.				
No	Long Term	No		Ongoing

TABLE 3.
CURRENT PROGRESS ON ACTION PLAN INITIATIVES

Action Taken?	Timeline	Priority Changed?	Comment (Describe progress or changed priority)	Status
Reconstruct and widen SR 522 Wayne Curve; increase intersection capacity by adding left turn lanes; enhance transit operations by adding Business Access and Transit lanes; transit priority improvements; raised median; widen 96th approaches to extend northbound left turn lane; street lighting and reconstruction of traffic signals.				
Yes		No	Project completed in June 2012.	Complete
To construct the missing link of the north-south arterial corridor of the 35th/39th corridor between 240th Street SE and 228th St SE.				
No	Long Term	No		No Progress
Raze and rebuild entire firehouse and add training tower and ground props.				
Yes	Short Term	Yes	Station was remodeled in 2009. No further action is to be taken on this.	Complete
Consolidate four critical facilities into one facility that enhances the ability to better service the general public and businesses within the community.				
Yes	Long Term	No	Location was determined and properties were purchased. Demolition of unneeded structures was completed September 2013. City Council is anticipated to make decision regarding construction schedule in first quarter 2014.	Ongoing
Provide disaster preparedness and awareness education to the general public and businesses within the community.				
Yes	Long Term	No	This is an on-going project to continue to bring disaster preparedness and awareness to the public.	Ongoing
To provide funding for immediate action to address landslides, erosion, deterioration, vandalism and spot hazardous locations.				
No	Long Term	No		Ongoing
Provide funding for safety improvements to the infrastructure other than street overlays and replacement. Such projects include guardrails, signing, crosswalks, minor curb replacement, and handicapped (ADA) ramps.				
Yes	Long Term	No	Grants received in June 2012 for safety improvements - 228th/Bothell-Everett Highway Intersection, 228th Corridor and citywide improvements. Projects are either under construction or in design phase and anticipated to be complete by 2015.	Ongoing
This project will provide capacity and safety improvements and include roadway widening to a five-lane roadway with intermittent median landscaping, bicycle lanes, curb, gutter, and sidewalk.				
Yes	Short Term	No	Grant funds were secured and construction is underway. Project anticipated to be complete in summer 2014.	Ongoing
Intersection improvements at SR 524 and widening the roadway in the southbound direction from two to three lanes from SR 524 to about 500 feet north of 220th St SE.				
No	Long Term	No		No Progress
Intended to address the safety and access concerns on SR 524 between SR 527 and 39th Ave SE. Access improvements will be limited to roadway widening to provide for left turn pockets and improve sight distances.				
No	Long Term	No		No Progress

TABLE 3.
CURRENT PROGRESS ON ACTION PLAN INITIATIVES

Action Taken?	Timeline	Priority Changed?	Comment (Describe progress or changed priority)	Status
The Multiway Boulevard will consist of four travel lanes, a left turn lane, two side landscape medians, two side lanes with parking and a wide sidewalk.				
Yes	Long Term	No	The City began Phase 1 (west side access lanes, etc.) of construction in June 2013. Funding is still needed for remaining phases.	Ongoing
Rehabilitate the existing bridge to eliminate its structural deficiency rating and to complete a seismic level 1 retrofit. The bridge is currently in need of miscellaneous structural repair, including resurfacing the bridge decking with concrete cement, upgrading the reinforced concrete girders, and installing vehicle railings.				
Yes		No		Complete
Widening of the existing two-lane facility to a five-lane facility with bicycle lanes, sidewalks; reconstruct the existing 2 lane bridge over North Creek to a 5 lane bridge and reconstruct traffic signals.				
Yes		No		Complete
Identify and address piping system networks and key infrastructure improvements regarding water and sewer service, distribution and conveyance. This project is to identify and address security and seismic improvements throughout the jurisdiction.				
Yes		No		Complete
Water system piping improvements at source connection at south end of the City which is designed to include provide automatic connection with alternate water supply.				
Yes		No		Complete
Construct a two-person remote aid station in the downtown area for the placement of Medics.				
No		Yes	This is no longer priority and will be removed from the initiatives.	No Progress
Redevelopment of well field for primary self-sustaining source water, and provide seismic upgrades to tank located at well -field site.				
No		Yes	Removed from Hazard Mitigation Plan	No Progress
Facility improvements for Public Works field operations department; improvements to include security measures for key equipment, supplies and personnel.				
Yes	Short Term	No	Built a new Public Works Operations Center in 2010	No Progress
City of Federal Way Annex				
Public education related to wide-spread utility outages				
Yes	Short Term	No		Ongoing
Public awareness campaign to encourage earthquake hazard mitigation actions				
Yes	Short Term	No	Worked with local Home Depot, Lowes, and Costco to hold presentations on home mitigation projects.	Complete
Create SARA EPCRA Tier II HAZMAT Facilities map for use in Emergency Operations Center				
No	Long Term	No		No Progress

TABLE 3.
CURRENT PROGRESS ON ACTION PLAN INITIATIVES

Action Taken?	Timeline	Priority Changed?	Comment (Describe progress or changed priority)	Status
Determine and complete retrofit plan to eliminate the potential of localized flooding related to 44th Avenue SW pond				
Yes	Short Term	No	Project Completed	Complete
Site-hardening of all City facilities				
Yes	Long Term	No	Continue to assess, identify, and correct areas of facilities needing safety upgrades or hardening.	Ongoing
Install GPS system to aid in resource allocation & tracking during an emergency event				
Yes	Short Term	No	Identify City vehicles equipped with GPS and monitoring system to improve real time information documentation.	Complete
City of Issaquah Annex				
Water system seismic retrofits				
Yes	Short Term	No	Highwood reservoirs received retrofitting in 2011 and the Cemetery reservoirs were retrofitted in 2012.	Ongoing
Mt. Hood Pump Station seismic rebuild				
No	Short Term	Yes	Water system priorities changed. Project remains in the Capital Facilities Plan with design scheduled for 2014 and construction in 2015.	No Progress
Flood warning gauge on Issaquah Creek north of Fifteen-Mile Creek				
Yes	Short Term	No	Project completed by Public Works in October 2011.	Complete
Flood hazard repetitive loss mitigation				
Yes	Short Term	No	Six single family homes elevated in 2011.	Complete
Promote CERT and Map Your Neighborhood programs				
Yes	Long Term	No	City sponsors at least two CERT classes annually and offers MYN facilitator training to CERT graduates and conducts ongoing MYN meetings.	Complete
City of Kent Local Hazard Mitigation Plan				
Prioritize seismic retrofit for critical facilities to meet the most current standards for new buildings to the maximum extent possible				
No	Long Term	No		No Progress
Mitigate the non-structural impacts of an earthquake on City owned critical facilities.				
Yes	Short Term	No	seismic mitigation to critical computer server room equipment seismic mitigation of several city workspaces	Ongoing
Use the Hazus computer modeling program to estimate loss				
No	Long Term	Yes	Staffing changes have pushed this priority to a long term goal	No Progress

**TABLE 3.
CURRENT PROGRESS ON ACTION PLAN INITIATIVES**

Action Taken?	Timeline	Priority Changed?	Comment (Describe progress or changed priority)	Status
Improve alert and notification methods to the citizens of Kent by implementing a reverse 911 system.				
Yes	Short Term	Yes	City of Kent and Kent Fire Department RFA now utilize Code Red emergency notification system	Ongoing
Enhance public notification system. Implement a public awareness campaign focused NOAA weather radios. Improve the existing Traffic Information System by increasing coverage area and adding alert beacons				
Yes	Short Term	No	Kent Emergency Management continues to provide a public education program that includes Community Emergency Response Team (CERT) training	Ongoing
Identify slope areas that threaten critical facilities due to lack of vegetation and erosion control. Prioritize and implement slope stabilization measures.				
No	Long Term	No		No Progress
Increase public education efforts toward preventing stovetop cooking fires the cause of most residential fires.				
Yes	Short Term	No	(In partnership with Kent Fire Department) Kent Fire RFA continues to provide public education programs that educate the public about kitchen fires.	Ongoing
Pre-identify lahar evacuation routes				
Yes	Short Term	Yes	Evacuation routes have been identified with an all hazard approach including flooding and lahar.	Ongoing
Identify reoccurring utility outage areas and work with utility providers to remove hazards along those areas.				
Yes	Short Term	No	Continue to improve areas by removing threats to utilities	Ongoing
Make available back-up power sources to vulnerable populations.				
No	Long Term	No	Grant funds would need to be obtained to complete this project. A grant source has not been identified.	No Progress
Construct a facility that would house a permanent Emergency Coordination Center.				
No	Long Term	No	Funds have not been identified to complete this task.	No Progress
City of Mercer Island Hazard Mitigation Plan Update				
Incorporate Hazard Mitigation policies into City Comprehensive Plan				
Yes		No		Complete
Develop/Maintain Watercourse CIP list				
Yes	Long Term	No		Ongoing
Rehabilitate damaged storm culverts				
Yes	Long Term	No		Ongoing
Large Ravine/Watercourse Projects				
Yes		No		Complete

**TABLE 3.
CURRENT PROGRESS ON ACTION PLAN INITIATIVES**

Action Taken?	Timeline	Priority Changed?	Comment (Describe progress or changed priority)	Status
Small Ravine/Watercourse Projects				
Yes	Long Term	No		Ongoing
Replace aging water mains				
Yes	Long Term	No		Ongoing
Sewer generator replacement program				
Yes	Short Term	No		Ongoing
Sewer rehab/replace				
Yes	Long Term	No		Ongoing
Emergency program				
Yes	Long Term	No		Ongoing
IT systems continuity				
Yes	Long Term	No		Ongoing
Firewise				
Yes	Long Term	No		No Progress
City of Pacific Annex				
Encourage and facilitate the development or updating of general plans and zoning codes to limit development in hazard areas				
			No progress reported.	
Enforce the building codes, the general plan and zoning ordinances of the City of Pacific, which will prevent or minimize damage to residential and commercial structures due to flooding events				
			No progress reported.	
Evaluate protocols, purchase emergency containment supplies, invest in notification systems, and supply neighborhood groups with emergency training and equipment				
			No progress reported.	
Inspect and retrofit the critical facilities of the City against failure from earthquake, snow and wind. Enforce the provisions of the latest edition of the Pacific building code for Pacific critical facilities, alterations and additions				
			No progress reported.	
Improve capacity of arterial routes. This includes West valley highway, Butte Avenue, Valentine Avenue South, and Stewart Road				
			No progress reported.	
Improve safety along arterial route of West Valley Highway				
			No progress reported.	
Install berm using earthen materials along the eastern side of the Pacific City Park				
			No progress reported.	

TABLE 3.
CURRENT PROGRESS ON ACTION PLAN INITIATIVES

Action Taken?	Timeline	Priority Changed?	Comment (Describe progress or changed priority)	Status
Work with external partners to identify dead or diseased trees for annual trimming or removal				
			No progress reported.	
Contract to construct seismic upgrades to Pacific city hall, community center and police station				
			No progress reported.	
City of Redmond Hazards Mitigation Plan				
To mitigate impacts involved with isolation following a severe hazard event, Redmond will develop outreach activities to enable Redmond residents, businesses and visitors to survive in-place for more than three days.				
Yes	Long Term	No	Participated in a wide variety of preparedness fairs and gave dozens of preparedness talks to the public, businesses and visitors throughout the whole community. Developed the Redmond Ready basic preparedness education class for City of Redmond employees and Redmond residents. Began delivering Redmond Ready classes in July 2012. Trained approximately 200 City of Redmond employees to make them Redmond Ready. Conducted several Redmond Ready Days to train the public in basic preparedness, First Aid, and CPR. Worked with Microsoft to develop the www.redmondready.org web portal, which promotes the program and which lives in the cloud and can be updated quickly by OEM staff during a disaster. Promoted the regional Make it Through preparedness campaign. Conducted Map Your Neighborhood classes. Conducted an average of three CERT classes every year. Partnered with the Redmond Citizens Corps Council and Amateur Radio Emergency Services (ARES) regarding community outreach. Worked with many partner agencies to develop a high-quality, low-cost emergency preparedness calendar for 2013 and 2014 that is a great year-round resource.	Ongoing
To ensure provision of vital services following a hazard event, Redmond will develop alternative service centers in less hazardous areas.				
Yes	Long Term	No	Fire Station 17 was built and went into service in March 2012. The station is located on Education Hill, away from the liquefaction zone in downtown Redmond. Future development will concentrate in both the Downtown and Overlake Urban centers. Overlake is away from the liquefaction zone.	Ongoing

**TABLE 3.
CURRENT PROGRESS ON ACTION PLAN INITIATIVES**

Action Taken?	Timeline	Priority Changed?	Comment (Describe progress or changed priority)	Status
To mitigate damage to vulnerable structures and infrastructure, Redmond will promote retrofitting with safe-to-fail mechanisms.				
Yes	Long Term	No	Emergency power generation was substantially upgraded at the Public Works Maintenance and Operations Center and at the Redmond Municipal Campus. Redundant network infrastructure has been added. Water tanks on Education Hill were seismically retrofitted. Public Works is in the process of their Buildings Facilities Condition Assessment, the outcome of which will give the city a better handle on the condition of our assets and what may need to be implemented. The Public Works construction group is looking at bridge seismic retrofits (such as 148th). Our bridges are rated for safety based on King County's bridge inventory system.	Ongoing
To mitigate against the loss of major transportation facilities in and around the City, Redmond will invest resources in building more resilient transportation networks.				
Yes	Long Term	No	1) Redmond is completing a grid network in both the Downtown and Overlake Urban Centers where most of the growth will be occurring in the future, 2) All of our bridges are inspected regularly and the existing bridges meet reasonable earthquake standards with the exception of the 148th Bridge north of Redmond Way which has funding for a seismic retrofit. All the new bridges and bridge replacements are designed to current earthquake standards, 3) City is developing a complete multi-modal transportation system to provide travel choices including bringing light rail to Overlake in 2023 and eventually to downtown, 4) Redmond has a state of the art Traffic Operations Center that has cameras at key intersections to monitor and change parking signals remotely to respond to changing traffic conditions, and 5) Redmond's R-TRIP program offers infrastructure for ride matching, transit route information, and periodic communication and incentives to encourage individuals to explore ways of getting between home and work that don't rely on driving alone and support finding a potential carpool partner or bus route that could be used in the event of an emergency. This program has nearly 29,000 registered users among employees and residents in Redmond. Further, by contract with King County Metro, we provide these services in our community.	Ongoing

TABLE 3.
CURRENT PROGRESS ON ACTION PLAN INITIATIVES

Action Taken?	Timeline	Priority Changed?	Comment (Describe progress or changed priority)	Status
To mitigate against the functional loss of business communities, Redmond will develop and deliver business outreach programs.				
Yes	Long Term	No	Police Department conducted Critical Incident Protocol (CIP) outreach regarding crime prevention and man-made hazards. Emergency Management conducted many preparedness sessions at businesses, helping businesses prepare their employees. As part of the City's Economic Development initiatives, the City has developed close communications and relationships with businesses through its One Redmond partnership (which took the place of the former Greater Redmond Chamber of Commerce) and neighborhood level business outreach which could be deployed to assist outreach and communication about emergency planning and operations. Past outreach has included: winter time promotions via the www.GOrtrip.com to encourage winter emergency planning and partnering with the Greater Redmond Transportation Management Association in 2012 to bring in Ed Gabriel, Principal Deputy Assistant Secretary for Preparedness and Response, US Heath and Services to raise awareness by businesses of all sizes about the need for emergency preparedness.	Ongoing
To mitigate impacts from expected increases in incidences of shallow flooding, Redmond will build a flood tolerant community able to accommodate increases in low impact flooding				
Yes	Long Term	No	Redmond does not allow development in the floodway and has adopted regulations for developments outside of the floodway but within the floodplain. One of those regulations requires compensating floodplain storage for these developments so we don't reduce our floodplain capacity. Redmond completed a large trunk line (storm drainage line) in the BNSF railroad right of way that will carry the 50 year storm for much of downtown. Additionally, Redmond is constructing an enormous stormwater vault in Overlake behind Sears. The vault will reduce flow rates from about 345 ac. The vault is about 1.5 ac in area and 20 feet deep. Two additional vaults are proposed in Overlake in the future including one to be constructed with the light rail station. Both the trunkline in downtown and the Overlake vaults should greatly reduce the risk of flooding in Redmond's urban centers.	Ongoing
City of Renton Hazard Mitigation Plan				
Establish a formal role for the Renton All Hazard Mitigation Planning Committee (Emergency Management Group) to develop a sustainable process to encourage, implement, monitor, and evaluate citywide mitigation actions.				
Yes	Short Term	No	EM is now represented in citywide planning efforts	Complete

TABLE 3.
CURRENT PROGRESS ON ACTION PLAN INITIATIVES

Action Taken?	Timeline	Priority Changed?	Comment (Describe progress or changed priority)	Status
Identify and pursue funding opportunities to implement mitigation actions.				
Yes	Short Term	No	Preparing to apply for 2014 bridge retrofit funding. Funding already secured for downtown library retrofit project.	Ongoing
Develop public and private sector partnerships to foster hazard mitigation activities.				
Yes	Short Term	No	Have increased awareness through public education activities, COAD outreach, CERT, and Citizen's Academy	Ongoing
Develop detailed inventories of at-risk buildings and infrastructure and prioritize mitigation actions				
Yes	Short Term	No	Inventory of buildings and roads/bridges complete for seismic. Need to add in other hazards and then prioritize. IT has inventory of all technology equipment and services, prioritized on basis of business need and greatest benefit. Recommend moving this project to Long Term.	Ongoing
Develop education programs aimed at mitigating the risk posed by hazards				
Yes	Long Term	No	Implemented education activities related to cyber-crime, vandalism. Have incorporated mitigation component directly into other public education programs including staff education for cybersecurity.	Complete
Integrate the Mitigation Plan findings into planning and regulatory documents and programs.				
Yes	Long Term	No	Case-by-case basis during project review; and integrated as appropriate during updates of the Critical Areas Ordinance and Comprehensive Plan Elements.	Ongoing
Integrate hazard, vulnerability and risk Mitigation Plan findings into enhanced Emergency Operations planning.				
Yes	Long Term	No	Implemented seismic fastening project at EOC and all fire stations	Complete
Complete an inventory of structures, critical facilities and important transportation or utility system components within mapped floodplains, including elevation data and structure/facility information.				
Yes	Short Term	No	Updated GIS layers to incorporate FEMA floodplain map information to allow it to be overlaid onto utility, transportation, building, aerial and topography layers to identify critical facilities in the floodplain.	Ongoing
Identify and implement cost-effective mitigation measures for high-risk structures, with the highest priority for critical facilities, transportation and utility components.				
Yes	Long Term	Yes	Duplicates other more specific projects in plans that are included under this umbrella. Recommend removal of project and focus on more specifics.	Ongoing
Identify and implement measures and policies to increase Renton's Community Rating System score to reduce flood insurance rates.				
Yes	Long Term	No	Updated City Surface Water Design Standards GIS floodplain layers to increase potential for a better CRS rating.	Ongoing

TABLE 3.
CURRENT PROGRESS ON ACTION PLAN INITIATIVES

Action Taken?	Timeline	Priority Changed?	Comment (Describe progress or changed priority)	Status
Continue to be a member of the National Flood Insurance Program to enable property owners in Renton to purchase flood insurance from FEMA and allow the City to receive flood disaster funding to repair damages due to flooding following a federally declared disaster.				
Yes	Long Term	No	Continuing to implement NFIP requirements and programs necessary to maintain eligibility. Successfully completed a Community Assistance Visit from FEMA in 2010 and 2012 that verified City is complying with NFIP requirements and is an eligible member of the NFIP.	Ongoing
Continue to require new construction of structures in the floodplain to be constructed in accordance with FEMA standards and the National Flood Insurance Program requirements, including requiring compensatory floodplain storage for filling of the floodplain.				
Yes	Long Term	No	Evaluate permits on a case-by-case basis, and report annually to FEMA. Work that has begun on revisions to the Critical Areas Regulations (to be completed in 2015) may result in some changes in code.	Ongoing
Implement the Reasonable and Prudent Measures identified in the NOAA Fisheries Biological Opinion regarding FEMA’s National Flood Insurance Program as required by FEMA.				
Yes	Long Term	No	Renton currently complies with the RPA by subscribing to Option 3, the permit-by-permit approach. A Critical Areas study or Biological Assessment is required. An update of the Critical Areas Ordinance (by 2015) will meet or exceed the RPA performance standards (Option 2).	Ongoing
Continue to enforce, maintain and update the Renton Critical Areas Regulations and Shoreline Master Program requirements.				
Yes	Long Term	No	Renton is in the process of updating the Critical Areas Regulations. An update of the Shoreline Master Program was completed and adopted on November 3, 2011.	Ongoing
Continue to perform maintenance dredging, maintenance of floodwalls and levees associated with the Army Corps of Engineers Cedar River Section 205 Flood Hazard Reduction Project.				
Yes	Long Term	No	Continued to implement sediment levels to determine need for next maintenance dredge. In 2013 initiated planning, design, and permitting work for the next maintenance dredge. Currently working with consultants and agencies to review the proposed dredging of the Cedar River, and to process necessary land use and environmental (SEPA) permits.	Ongoing

**TABLE 3.
CURRENT PROGRESS ON ACTION PLAN INITIATIVES**

Action Taken?	Timeline	Priority Changed?	Comment (Describe progress or changed priority)	Status
Continue to implement the Surface Water Utility programs related to flood hazard management, which include the Capital Improvement Program, engineering program, maintenance and operations program, public education and customer service programs.				
Yes	Long Term	No	Water Utility to review projects for compliance with storm water regulations. Public Works is also taking over maintenance of stormwater ponds and vaults in residential projects (formerly the responsibility of the HomeOwners Associations). Continuing to fund and implement all Surface Water Utility programs. 2013 Surface Water Utility CIP budget is $10 million.	Ongoing
Adopt storm water design standards equivalent to the Ecology 2005 Stormwater Management Manual for Western Washington to better control the quantity and quality of storm water runoff from new construction and redevelopment projects and meet the requirement of the Phase II National Pollutant Discharge Elimination System permit requirements.				
Yes	Long Term	No	Have adopted local updates to the King County Surface Water Design Manual. Also completed update of City Surface Water Design Standards to meet Ecology NPDES Municipal Stormwater Permit requirements on February 10, 2010. Next update must be completed by or before December 31, 2016.	Complete
Integrate flood hazard reduction with other objectives related to water quality protection, habitat protection and habitat restoration efforts including complying with the Clean Water Act Phase II National Pollutant Discharge Elimination System permit, the Endangered Species Act and the regional salmon recovery efforts.				
Yes	Long Term	Yes	Vague language, already covered in other areas, including compliance with ecological mandates. Recommend removal of this project.	Ongoing
Continue to be consistent with the King County Flood Hazard Reduction Plan.				
Yes	Long Term	No	Continuing to work with the King County Flood Control District to implement regional flood hazard reduction projects, programs and policies.	Ongoing
Continue to participate in the King County Flood Warning System and the King County Flood Control Zone District				
Yes	Long Term	No	Continue to utilize the King County Flood Warning System for response to flooding due to storms. Attend annual pre-flood season Flood Warning coordination meetings.	Ongoing
Continue to be a member of the FEMA Community Rating System that enables property owners to obtain flood insurance at a reduced rate				
Yes	Long Term	No	Continuing membership in the FEMA CRS program. Current rating is 6. CRS Re-verification review schedule for November 7, 2013.	Ongoing

TABLE 3.
CURRENT PROGRESS ON ACTION PLAN INITIATIVES

Action Taken?	Timeline	Priority Changed?	Comment (Describe progress or changed priority)	Status
Re-evaluate future land use and zoning designations in FEMA mapped 100-year floodplain areas				
No	Long Term	No	The Comprehensive Plan Update and Critical Areas Ordinance update may involve the re-evaluation of land uses and zoning designations in the FEMA mapped 100-year floodplain areas.	No Progress
Complete an inventory of structures, critical facilities and important transportation or utility system components in locations with a history of severe or repetitive flooding.				
Yes	Short Term	No	Updated GIS layers to incorporate FEMA floodplain map information to allow it to be overlaid onto Utility, Transportation, building, aerial and topography layers to identify critical facilities in the floodplain.	Ongoing
Evaluate and improve notification, evacuation and response planning for areas within the potential inundation area for failure of the Hanson Dam.				
Yes	Short Term	No	Completed in 2011 after 2 years of operational planning across multiple departments and jurisdictions.	Complete
For locations with repetitive flooding and significant damages or road closures, determine and implement mitigation measures such as upsizing culverts or storm water drainage capacity.				
Yes	Long Term	No	Existing flooding problems and projects to solve them are identified in the Surface Water Utility CIP and that is updated as part of the City budget process.	Ongoing
Maintain copies of high-resolution maps of dam failure inundation areas and update emergency response plan, including public notification and evacuation routes.				
Yes	Short Term	No	Complete pending the map revisions of evacuation routes that were modified slightly in 2012.	Ongoing
Research seismic vulnerability assessments for Howard Hanson Dam and Chester Morse Dam and lobby dam owners to make seismic improvements as necessary.				
No	Short Term	Yes	Outside of staff's ability to influence the projects. Recommend removal.	No Progress
Enhance tree-trimming efforts especially for transmission lines and trunk distribution lines.				
No	Short Term	Yes	Tree trimming activity around power lines is done by certified persons. Staff work with PSE on their plans for large-scale projects, including tree removal per their recommendation, not tree trimming as specified in this project. Recommend removal of the project from the plan.	No Progress
Encourage property owners to trim trees near service drops to individual customers.				
No	Short Term	Yes	Outside of the city's area of responsibility, belonging to Puget Sound Energy instead. Recommend removal of project.	No Progress

**TABLE 3.
CURRENT PROGRESS ON ACTION PLAN INITIATIVES**

Action Taken?	Timeline	Priority Changed?	Comment (Describe progress or changed priority)	Status
Ensure that all critical City facilities in Renton have sufficient backup power and emergency operations plans to deal with power outages.				
Yes	Long Term	Yes	Added generator transfer switch to Renton Community Center. Recommend removal of project, however, for two reasons: 1) generators are not a true mitigation project, and 2) remaining locations are not feasible for generator placement	Complete
Consider upgrading lines and poles to improve wind/ice loading, undergrounding critical lines, and adding interconnect switches to allow alternative feed paths and disconnect switches to minimize outage areas.				
No	Long Term	Yes	Outside of the city's area of responsibility, belonging to Puget Sound Energy. Recommend removal of project from the plan.	No Progress
Encourage new developments to include underground power lines.				
Yes	Long Term	No	Implemented on a project-by-project basis. Required by RMC, however, waiver of this requirement is still possible on a case-by-case basis.	Ongoing
Evaluate the seismic vulnerability of critical city-owned buildings, utilities and infrastructure and establish priorities to retrofit or replace vulnerable facilities to ensure adequate seismic performance of critical facilities.				
Yes	Short Term	No	Engineering studies were conducted on the 200 Mill building in 2012. Other buildings have been evaluated. Bridges are evaluated every two years. Recommend moving this to a long-term project as it is taking more time and budget than initially anticipated.	Ongoing
Conduct a sidewalk survey of residential, commercial and industrial buildings in Renton using FEMA's Rapid Visual Screening to identify especially vulnerable buildings, raise awareness and encourage mitigation actions.				
No	Short Term	Yes	No available staff to carry out this work. Recommend removing it as a short term project and turning it into a long term project should staffing levels increase, or delete it altogether.	No Progress
Disseminate FEMA pamphlets to educate homeowners about structural and non-structural retrofitting of vulnerable homes and encourage retrofit.				
Yes	Short Term	No	Pamphlets are available either on-line or in the Customer Service Area at City Hall, or upon request from Emergency Management.	Ongoing
Obtain funding and retrofit important public facilities with significant seismic vulnerabilities.				
Yes	Long Term	No	Fire Station 11 seismic retrofit completed in December 2009. Contracted with District 40 and provided seismic retrofit to Fire Station 17 in early 2013. Seismic retrofit of downtown Renton library scheduled for 2014.	Ongoing
Complete the inventory of locations where buildings or infrastructure are subject to landslides.				
Yes	Short Term	No	GIS data updates clearly show landslide areas overlaid with critical infrastructure and buildings.	Complete

**TABLE 3.
CURRENT PROGRESS ON ACTION PLAN INITIATIVES**

Action Taken?	Timeline	Priority Changed?	Comment (Describe progress or changed priority)	Status
Consider landslide mitigation actions for slides seriously threatening buildings or infrastructure.				
No	Long Term	Yes	No currently identified building or infrastructure threats. Recommend removal of this project.	No Progress
Limit future development in high landslide potential areas.				
Yes	Long Term	No	Existing code prohibits or limits development in high landslide areas, and requires geotechnical studies and specific construction techniques in order to develop structures. The CAO update will also revisit these regulations.	Ongoing
Update public emergency notification procedures for ash fall events.				
Yes	Short Term	Yes	Public emergency notification procedures have been updated to include placement in 2011 of weather proof bulletin boards at each Renton School District school and the Golf Course should conventional communications fail.	Complete
Update emergency response planning for ash fall events.				
No	Long Term	No	Response oriented, not a true mitigation project. Recommend removing this project.	No Progress
Evaluate capability of water treatment plant to deal with high turbidity from ash falls and upgrade treatment facilities and emergency response plans to deal with ash falls.				
No	Short Term	Yes	Outside of the city's area of responsibility, belonging to METRO instead. Furthermore, city water supply comes from groundwater well system, which is not effected by volcanic ash fallout. Treatment processes are covered. Recommend removal of this project as not applicable.	No Progress
Require geological or geotechnical engineering studies before permitting new construction in identified coal mine hazard areas.				
Yes	Long Term	No	Studies are required at the time of land use permits and/or environmental review.	Complete
Ensure that first responders have readily available site-specific knowledge of hazardous chemical inventories in Renton.				
Yes	Short Term	Yes	Completed annually. Recommend removal of project for two reasons: 1) Response oriented, so not a true mitigation project, and 2) completed annually already as part of professional standards and mandates.	Complete
Enhance emergency planning, emergency response training and equipment to address hazardous materials incidents.				
Yes	Short Term	Yes	Completed annually. Recommend removal of project for two reasons: 1) Response oriented, so not a true mitigation project, and 2) completed annually already as part of professional standards and mandates.	Complete

TABLE 3.
CURRENT PROGRESS ON ACTION PLAN INITIATIVES

Action Taken?	Timeline	Priority Changed?	Comment (Describe progress or changed priority)	Status
Enhance emergency planning, emergency response training and equipment to address potential incidents of terrorism.				
Yes	Long Term	Yes	Completed annually. Recommend removal of project for two reasons: 1) Response oriented, so not a true mitigation project, and 2) completed annually already as part of professional standards and mandates.	Complete
Upgrade physical security detection and response capability for critical facilities, including water system.				
Yes	Long Term	Yes	Updated security and remote telemetry systems are in place for water system. Intrusion detection already present at other critical city facilities, updated in 2012. Additional physical security detection is not deemed necessary based on current risk assessment. Recommend removal of this project.	Complete
Evaluate and implement hardening measures for highly vulnerable critical facilities.				
Yes	Long Term	Yes	Upon reevaluation of risk, there are no physical facilities owned by Renton that have not already been hardened against potential terrorism to the degree that is feasible. IT system policies already improve security against cyber-attack through password hardening, SPAM filtering, virus protection and limiting internal network to the internet, and are ongoing by city policy. Recommend removal of this project.	Complete
Identify and establish secure surveillance cameras and monitoring at all critical infrastructure.				
Yes	Long Term	Yes	Cameras installed at police entrance to City Hall, Liberty Park, the bus mall, and other locations. Based on current risk assessment, further installations are not necessary to augment existing intrusion detection systems, and not feasible since no staff are available to monitor. Recommend removal of project.	Complete
Chemical, biological, radiological, nuclear and explosives detection and security devices/elements integrated at critical city infrastructure.				
No	Long Term	Yes	Not feasible or appropriate based on current risk assessment by police. Recommend removal of project.	No Progress
City of Shoreline Multijurisdictional Hazard Mitigation Plan Update				
Target higher risk neighborhoods for specific risk reduction measures				
Yes	Long Term	No	Targeted 7 Neighborhood Associations is complete and will continue as an on-going focus due to their vulnerabilities.	Complete
Continue and expand the delivery of risk reduction outreach programs by City & Fire staff, to general populations of households and businesses				
Yes	Long Term	No	City and Fire trained a cadre of staff in ATC 20, 21, and 54. These staff members are now used to assist in Public Education of households and businesses.	Complete

TABLE 3.
CURRENT PROGRESS ON ACTION PLAN INITIATIVES

Action Taken?	Timeline	Priority Changed?	Comment (Describe progress or changed priority)	Status
Increase GIS capability through partnering with fire department				
Yes	Short Term	No	GIS capability built and now is an on-going maintenance to the data base that was developed.	Complete
The City and Fire Department will participate in the planning/assessment activities of utility service providers				
Yes	Long Term	No	During this 5 year period all of our Franchise agreements with Utility providers were negotiated and now have stronger language about how identified risks are being addressed.	Complete
Establish safe places of refuge within walking distance of residents				
Yes	Long Term	No	All schools, community centers and many of the Faith Based organizations have been inventoried and have been mapped as possible places of refuge during a disaster.	Complete
Develop and deliver business outreach program				
Yes	Long Term	No	We have delivered many Business outreach programs to our business community, to include a 4 hour workshop on Business Continuity Planning. We will continue to do so as part of as our Pub Ed outreach program.	Complete
Retrofit or replace vulnerable city owned facilities and infrastructure				
Yes	Long Term	No	We did complete the replacement of the identified bridge to an isolate community. We did sign a mutual aid agreement with the Fire District to use Fire Facilities if we were to lose to use of the non-retrofitted Police Station. We did close the two Police Store Front facilities that were located in leased non-retrofitted buildings. We did explore the grant funding for replacement of the current police facility - that is in a non-retrofitted structure. We were not eligible for grant funds. The City is in the process of trying to decide how best to fund a new facility for the police department or move them into the City Hall, which was built in 2010. While City Hall was not built to a critical facility standard, there may be away to retrofit some of it to allow for the police to move into a newer facility that is better prepared to withstand a catastrophic earthquake than its current one. It is very expensive to build a police facility and currently the city financial outlook doesn't appear to have the capability of building a new facility in the foreseeable future.	Ongoing
Reduce flood damage within Ronald Bog community				
Yes	Short Term	No	Flood mitigation project completed - reduced flooding in the impact area.	Complete

TABLE 3.
CURRENT PROGRESS ON ACTION PLAN INITIATIVES

Action Taken?	Timeline	Priority Changed?	Comment (Describe progress or changed priority)	Status
City of Snoqualmie Hazard Mitigation Plan Update				
S-1—Develop a post-disaster action plan for all hazard of concern that address: debris management, historical data gathering, substantial damage assessment, and grants management. This plan would be an appendix to the City's Emergency management plan.				
			No progress reported.	
S-2—Adopt the updated City of Snoqualmie Hazard Mitigation Plan as an element of the City Comprehensive plan to assure linkage between the 2 documents				
			No progress reported.	
S-3—Continue to acquire FEMA elevation certificates for all structures within the mapped floodplain for which the city does not currently have one.				
			No progress reported.	
S-4—Continue to pursue feasible, cost effective, home elevation projects, targeting identified repetitive loss or frequently flooded properties within the Snoqualmie floodplain.				
			No progress reported.	
S-5—Consider the adoption of a "split-flow" floodway as an alternative to the regulatory floodway in effect for the City.				
			No progress reported.	
S-6—Re-map the City of Snoqualmie floodplain utilizing best available data and generating a mapped based product that will actively support hazard mitigation and land use decision making within the City				
			No progress reported.	
S-7—Consider amending the City's flood damage prevention ordinance to add language that will track substantial improvements and damages cumulatively, to leverage Increased Cost of Compliance (ICC) opportunities for flood insurance policy holders.				
			No progress reported.	
S-8—Considered adopting a higher regulatory freeboard standard above the current 1-foot standard.				
			No progress reported.	
S-9—Maintain Snoqualmie's compliance and good standing under the National Flood Insurance Program				
			No progress reported.	
S-10—Continue to maintain or enhance the City's classification under the Community Rating System				
			No progress reported.	
S-11—Adopt the City of Snoqualmie Stormwater Management plan.				
			No progress reported.	
S-12—Continue to pursue feasible, cost-effective property acquisition opportunities along the Snoqualmie River front				
			No progress reported.	

**TABLE 3.
CURRENT PROGRESS ON ACTION PLAN INITIATIVES**

Action Taken?	Timeline	Priority Changed?	Comment (Describe progress or changed priority)	Status
S-13—Consider regulatory prohibition on the use of wood (cedar) shingle roof covering or siding in urban-wildland interface areas, or areas deemed susceptible to wildfire exposure				
			No progress reported.	
S-14—Consider an increase in the building setback/spacing requirement for new construction in areas deemed susceptible to wildfire exposure				
			No progress reported.	
S-15—Join Firewise program by adopting Firewise programs and policies in the management of the urban/wildland interface areas within Snoqualmie				
			No progress reported.	
S-16—Consider planting standards in Wildland buffer areas to use only loose branching habits, non-resinous woody material, high moisture content leaves and limited seasonal dead debris and other varieties that possess fire resistive traits.				
			No progress reported.	
S-17—Develop a public outreach program teaming with home improvement vendors educating the public on ways to protect their property form the potential impacts of all hazards of concern.				
			No progress reported.	
S-18—Consider building code amendments that would harden new and existing structures from the potential impacts of earthquakes				
			No progress reported.	
S-19—Conduct seismic vulnerability study of critical facilities identified by City emergency managers.				
			No progress reported.	
S-20—Promote the structural and non-structural seismic retrofit of structures built before 1974 by a targeted outreach to the property owners of these structures.				
			No progress reported.	
S-21—Continue and/or enhance where feasible, the city's ongoing drainage system maintenance program to reduce or minimize the impacts from stormwater flooding within the City.				
			No progress reported.	
S-22—The City of Snoqualmie's North Well Field well # 6, 7 and 8 currently lack permanent back-up generation. A permanent standby generator needs to be installed to provide continuous service at this critical water service delivery facility				
			No progress reported.	
S-23—The Fisher Creek Booster Station currently lacks back up generation. A permanent standby generator needs to be installed to provide continuous service at this critical water service delivery facility. This site has space inside the building designed for a Generator.				
			No progress reported.	

**TABLE 3.
CURRENT PROGRESS ON ACTION PLAN INITIATIVES**

Action Taken?	Timeline	Priority Changed?	Comment (Describe progress or changed priority)	Status
S-24—To alleviate stormwater flooding problems along Railroad Avenue SE between SE Fir Street and SE King Street: Install new 12-inch diameter pipeline along Railroad Avenue SE from SE King Street to SE Fir Street. Connect to existing outfall to Snoqualmie River. Install new 12-inch diameter pipeline between Railroad Avenue SE and the Snoqualmie River.				
			No progress reported.	
S-25—Address stormwater flooding problems due to undersized storm drain system in vicinity of Doone Avenue SE and SE Newton Street. • Replace existing storm drain pipeline on Doone Avenue SE with new 12- and 24-inch diameter pipeline. Connect to existing ditch at south end of Doone Avenue SE. • Install new 12-inch diameter pipeline along SE Newton from Olmstead Place SE to Doone Avenue SE. • Connect to new storm drain at Doone Avenue SE. • Improve existing ditch for conveyance and water quality treatment				
			No progress reported.	
S-26—Address stormwater flooding problems due to lack of storm drain system on Railroad Avenue SE between SE Delta Street and SE 90th. Install new 18-inch diameter storm drain pipeline along Railroad Avenue SE from SE Delta Street to SE 90th Street. Connect to existing storm drain system at SE 90th Street.				
			No progress reported.	
S-27—Address stormwater flooding problems due to lack of storm drain system on SE Northern Street and Railroad Place SE. Ponding on 38200 block of SE Northern Street and east side of Railroad Avenue SE for extended periods during heavy rain events. Obstruction in the existing storm drain system on west side of Railroad Place SE is blocked due to a pipe failure or and obstruction in the pipeline.				
			No progress reported.	
S-28—Address stormwater flooding problems due to lack of storm drain system on 384th Avenue SE between SE River Street and SE Newton Street and an undersized storm drain system between SE Newton Street and outfall to wetland.				
			No progress reported.	
S-29—Address stormwater flooding problems due to lack of storm drain system on SE Alder Street, SE Hemlock Street, SE Spruce Street and SE Walnut Street. • Install new 12-inch diameter pipeline along SE Alder Street. Connect to existing storm drain at Meadowbrook Way SE. • Install new 12-inch diameter pipeline along SE Hemlock Street. Connect to existing storm drain at Meadowbrook Way SE. • Install new 12-inch diameter pipeline along SE Spruce Street. Connect to existing storm drain at Meadowbrook Way SE. • Install new 12-inch diameter pipeline along SE Walnut Street. Connect to existing storm drain at Meadowbrook Way SE.				
			No progress reported.	
S-30—Address stormwater flood problems due to lack of drainage conveyance system on SE Maple Street and Maple Avenue SE. • Install new 18-inch diameter pipeline along SE Maple Street from Maple Avenue SE to Johnson Slough. Install new water quality treatment facility. • Install new 18-inch diameter pipeline along Maple Avenue SE from 7900 block to SE Maple Street. Connect to new pipeline at SE Maple Street.				

TABLE 3.
CURRENT PROGRESS ON ACTION PLAN INITIATIVES

Action Taken?	Timeline	Priority Changed?	Comment (Describe progress or changed priority)	Status
			No progress reported.	
S-31—Address stormwater flood problems due to lack of drainage conveyance system on SE Beta Street, SE Delta Street, SE Epsilon Street, and Falls Avenue SE. • Install new 12-inch diameter pipeline along SE Beta Street from Euclid Avenue SE to Schusman Avenue SE. Connect to existing storm drain at Schusman Avenue SE. • Install new 12-inch diameter pipeline along SE Delta Street from Falls Avenue SE to Schusman Avenue SE. Connect to existing storm drain at SE Schuman Avenue Street • Install new 12-inch diameter pipeline along SE Epsilon Place. Connect to existing storm drain at Schusman Avenue SE. • Install new 12-inch diameter pipeline along Falls Avenue SE. connect to new pipeline at SE Epsilon Place.				
			No progress reported.	
S-32—Address stormwater flood problems due to lack of drainage conveyance system in vicinity of SE Cedar Street, SE Fir Street, Pine Avenue SE and SE 80th Street • Install new 18-diameter pipeline at Pickering Court SE. Outfall to wetland area. • Install new 12-diameter pipeline at SE Fir Street at SE Cedar Street. Connect to new storm drain at Pickering Court SE. • Install new 12-diameter pipeline at Pine Avenue SE. Connect to new storm drain at Pickering Court SE. • Install new 12-diameter pipeline at SE 80th Street. Connect to new storm drain at Pickering Court SE.				
			No progress reported.	
S-33—Promote realignment and increase inspections along State Route 202 within the City north of Snoqualmie Falls to reduce risk from landslides that in the past have resulted in significant economic losses to tourism. Work with Washington Department of Transportation to identify areas along State Route 202. Seek ways to improve slope stability and/or seek funding to plan for and repair future slope failures to reduce the potential for repetitive losses. And to provide for additional Citizen access				
			No progress reported.	
S-34—Develop a public outreach strategy that maximizes the City's capabilities through its ongoing programs that provide multiple messages that support all phases of emergency management				
			No progress reported.	
S-35—Conduct a vulnerability assessment of water and wastewater utilities for exposure to all identified hazards of concern.				
			No progress reported.	
S-36—Review utility designs and standards for safety and competence under natural and human caused disasters.				
			No progress reported.	
S-37—Participate in the Basin Technical Committee process of the King County Flood Control District to leverage resources for flood hazard mitigation.				
			No progress reported.	
S-38—Continue to participate/support the King County Public Outreach Strategy developed to coordinate countywide outreach programs credited under the Community Rating System.				
			No progress reported.	

**TABLE 3.
CURRENT PROGRESS ON ACTION PLAN INITIATIVES**

Action Taken?	Timeline	Priority Changed?	Comment (Describe progress or changed priority)	Status
S-39— Implement Sandy Cove high bank feasibility study to identify bank stabilization alternatives for of the king Street lot, immediately adjacent to Sandy cove Park				
			No progress reported.	
S-40— Seek funding for the placement of a new stream flow gauge at the City of Snoqualmie above the falls that will accurately depict in channel flows at the City during high water events.				
			No progress reported.	
S-41— Replace two small bridges that have rotting wood pilings and abutments. These facilities were damaged by the Nisqually earthquake that required repair by King County bridge crews. Recent bridge inspection records indicate repair would be as costly as complete reconstruction.				
			No progress reported.	
City of Tukwila Hazard Mitigation Plan				
Construct a new City Emergency Operations Center facility to support emergency response and recovery coordination				
Yes	Long Term	Yes	Part of 2014 City Facilities Plan	Ongoing
Construct new City maintenance and operations center to support critical City functions including fleet services, facilities maintenance, water, sewer, surface water, streets and traffic control operations				
Yes	Long Term	Yes	Part of 2014 City Facilities Plan	Ongoing
Replace the existing Boeing Access Road bridge with a 340' long concrete or steel bridge structure. Bridge will be 110' wide curb to curb with sidewalks on both sides				
Yes	Short Term	Yes	Design to be completed in 2014 and 2015 construction	Ongoing
Construct a concrete containment wall (4' high by 275' long) along the west side of Interurban Avenue South				
Yes	Short Term	Yes	Design completed in 2013 and 2014 construction	Ongoing
City of Woodinville Annex to North King and South Snohomish Counties Regional Mitigation Plan for Natural Hazards				
WV-01-MH-ST— Evaluate Old Woodinville School House for reconstruction and/or replacement. Follow up with appropriate replacement or repair/retrofit activities.				
Yes	Short Term	No	Actively studying costs of rehabilitation for possible voter-approved bond measure in April 2014.	Ongoing
WV-02-MH-ST— Install emergency generator at Carol Edwards Center, Building D. (The Carol Edwards Center is designated and used as an emergency shelter as needed and appropriate.)				
No	Long Term	Yes	In light of the closure of Woodinville's Parks and Recreation Department and recent ADA rulings related to emergency shelters, the City does not view this shelter as a primary shelter and has removed this project from its 6-Year Capital Improvement Plan.	No Progress
WV-03-MH-ST— SR 202 Retaining Wall Repair.				
Yes	Short Term	No	Project completed in 2010.	Complete

**TABLE 3.
CURRENT PROGRESS ON ACTION PLAN INITIATIVES**

Action Taken?	Timeline	Priority Changed?	Comment (Describe progress or changed priority)	Status
WV-04-MH-ST— 171st Street Slide Repair				
Yes	Short Term	No	Project completed in 2010.	Complete
WV-05-MH-ST— Enforce code requiring electrical utilities to use underground construction methods where possible to reduce power outages and minimize potential for injuries from downed lines.				
Yes	Long Term	No	City Council passed Ordinance No. 517 in 2010 requiring new development and redevelopment to underground utilities.	Complete
WV-06-MH-LT— Sammamish Bridge Replacement. As a primary arterial, this is a key route for emergency vehicles and public safety.				
Yes	Short Term	Yes	Project currently at 60% design; working on property acquisition matters related to the project; construction tentatively scheduled for summer 2014.	Ongoing
WV-07-E-ST— Conduct non-structural retrofit activities.				
No	Long Term	No		No Progress
WV-08-F-ST— 171st Storm Drain Installation. Reduce urban flooding by installing 3,000 linear feet of piped drainage system.				
No	Long Term	Yes	New development along 171st Ave NE will begin construction in 2014 and will include adjustments to Woodin Creek and adjacent roadway, which will help to eliminate urban flooding.	Ongoing
WV-09-F-ST— BNRP Outfall				
Yes	Short Term	No	Project completed in 2010.	Complete
WV-10-F-ST—Surface Water Master Plan				
Yes	Short Term	No	Plan adopted in 2010.	Complete
WV-11-F-LT— Little Bear Creek 134th Culvert. Replace existing culverts.				
No	Long Term	No	Have discussed the project with various stakeholders, including Adopt-A-Stream Foundation, FEMA, and affected property owners. Have not been able to resolve technical and property acquisition challenges at this time.	No Progress
WV-12-F-LT— Woodin Creek Surface Water Improvement. Sediment from bank erosion and creek bed scour has accumulated in various areas in the Woodin Creek channel along NE 171st Street, resulting in decreased flow capacity in Woodin Creek and has caused road and private property flooding. This project will also lessen impacts on fish.				
No	Long Term	Yes	New development along NE 171st Ave will begin construction in 2014 and will include adjustments to Woodin Creek and adjacent roadway, which will help to eliminate urban flooding.	Ongoing
WV-13-F-LT— 195th Culvert Enhancement.				
No	Long Term	No		No Progress

TABLE 3.
CURRENT PROGRESS ON ACTION PLAN INITIATIVES

Action Taken?	Timeline	Priority Changed?	Comment (Describe progress or changed priority)	Status
Covington Water District Annex				
Install seismic retrofits to Tank 4				
Yes	Short Term	No	Seismic evaluation has been completed. Retrofit in 2014.	Ongoing
Conduct seismic evaluation study and install seismic retrofit to Tank 2B				
Yes	Short Term	No	Tank has been seismically retrofitted.	Complete
Conduct seismic evaluation study and install seismic retrofit to Tank 2A				
Yes	Short Term	No	Tank was demolished instead of retrofitted.	Complete
Conduct seismic evaluation study and install seismic retrofit to Tank 3				
Yes	Short Term	No	Seismic evaluation is completed. Retrofit in 2014.	Ongoing
Conduct seismic evaluation study and install seismic retrofit to Tank 1B				
Yes	Short Term	No	Seismic evaluation and retrofit will be completed in 2015.	Ongoing
Conduct seismic evaluation study and install seismic retrofit to Tank 1A				
Yes	Short Term	No	Seismic evaluation and retrofit will be completed in 2015.	Ongoing
Relocation and anchoring of approximately 2000 feet of 8 inch water main at the Soos Creek crossing				
Yes	Long Term	No	No progress to date.	No progress
Highline Water District Annex				
Install seismic activated control valves at the Crestview and Mansion Hill Reservoir sites.				
Yes	Short Term	No	Seismic control valves have been installed.	Complete
Replace the current disinfection process and equipment from gaseous chlorine to onsite sodium hypochlorite generation at the Tyee, Angle Lake and Des Moines Treatment Plants.				
Yes	Short Term	No	Design completed. Project construction scheduled for 2014.	Ongoing
Install backup power generator and appurtenances at the Des Moines Treatment Plant.				
No	Short Term	No	Project budgeted for 2016.	Ongoing
King County Water District 19 Annex				
Develop training for community emergency responders such as fire and rescue improving understanding of proper fire hydrant operation and protecting the system from transients.				
Yes	Short Term	No	Forwarded M&H Fire Hydrant Co. publication A-4.11.	Ongoing
Install emergency generators in additional designated District-owned critical facilities				
Yes	Long Term	No	Added generators to 5-year capital plan.	Ongoing
Develop additional source(s) of water to provide backup supplies				
Yes	Long Term	No	To date added one source, adding seconds in 2013.	Ongoing

TABLE 3.
CURRENT PROGRESS ON ACTION PLAN INITIATIVES

Action Taken?	Timeline	Priority Changed?	Comment (Describe progress or changed priority)	Status
King County Water District 111 Hazard Mitigation Plan				
Site Evaluation: Tank/Reservoir Site				
Yes	Short Term	No	The District completed a seismic analysis of the 2 million gallon reservoir. There are other facilities on this site that still need to be evaluated including two buildings, two reservoirs and one wall.	Ongoing
Seismic Evaluation: District Office				
No	Short Term	No		No Progress
Water Main Replacement: Facility #48				
No	Long Term	No		No Progress
Water Main Replacement: Facility #28				
No	Long Term	No		No Progress
Water Main Replacement: Facility #51				
No	Long Term	No		No Progress
Water Main Replacement: Facility #26				
No	Long Term	No		No Progress
Water Main Replacement: Facility #45				
No	Long Term	No		No Progress
Water Main Replacement: Facility #32				
No	Long Term	No		No Progress
Water Main Replacement: Facility #46				
No	Long Term	No		No Progress
Water Main Replacement: Facility #38				
No	Long Term	No		No Progress
Sammamish Plateau Water and Sewer District Annex				
Redundant repeater installation				
Yes	Short Term	No	Completed	Complete
Soos Creek Water District Hazard Mitigation Plan				
Portable Generator Receptacle Retrofit: Pump Station #2				
No	Short Term	Yes		Complete
Portable Generator Receptacle Retrofit: Pump Station #1				
No	Short Term	No		No Progress

TABLE 3.
CURRENT PROGRESS ON ACTION PLAN INITIATIVES

Action Taken?	Timeline	Priority Changed?	Comment (Describe progress or changed priority)	Status
Permanent Generator: Pump Station #2				
No	Long Term	No		No Progress
Permanent Generator: Pump Station #1				
No	Long Term	No		No Progress
Lift Station Retrofit: Lift Station #14				
Yes	Long Term	No		Complete
Lift Station Retrofit: Lift Station #12				
Yes	Long Term	No		Complete
North Force Main: Lift Station #5B				
No	Long Term	No		Ongoing
Southwest Suburban Sewer District Annex				
Salmon Creek Wastewater Treatment Plant landslide mitigation project				
			No progress reported.	
Seismic feasibility study of wastewater treatment plant and collection system				
			No progress reported.	
Implement projects recommended by feasibility study				
			No progress reported.	
Continuity of operations plan				
			No progress reported.	
Emergency fuel storage tanks				
			No progress reported.	
King County Fire District 4 (Shoreline Fire Department) Annex to City of Shoreline Multijurisdictional Hazard Mitigation Plan Update				
Target higher risk neighborhoods for specific risk reduction measures				
Yes	Long Term	No	Targeted 7 Neighborhood Associations is complete and will continue as an on-going focus due to their vulnerabilities.	Complete
Continue and expand the delivery of risk reduction outreach programs by City & Fire staff, to general populations of households and businesses.				
Yes	Long Term	No	City and Fire trained a cadre of staff in ATC 20, 21, and 54. These staff members are now used to assist in Public Education of households and businesses.	Complete
Increase GIS capability through partnering with Fire Department				
Yes	Short Term	No	GIS capability built and now is an on-going maintenance to the data base that was developed.	Complete

TABLE 3.
CURRENT PROGRESS ON ACTION PLAN INITIATIVES

Action Taken?	Timeline	Priority Changed?	Comment (Describe progress or changed priority)	Status
The City and Fire Department will participate in the planning/assessment activities of utility service providers				
Yes	Long Term	No	During this 5 year period all of our Franchise agreements with Utility providers were negotiated and now have stronger language about how identified risks are being addressed.	Complete
Establish safe places of refuge within walking distance of residents				
Yes	Long Term	No	All schools, community centers and many of the Faith Based organizations have been inventoried and have been mapped as possible places of refuge during a disaster.	Complete
King County Fire District 37 (Kent Fire Department) Annex to City of Kent Local Hazard Mitigation Plan				
Mitigate the non-structural impacts of an earthquake on District owned critical facilities.				
Yes	Short Term	No	seismic mitigation to critical computer server room equipment seismic mitigation of several city workspaces	Ongoing
Improve alert and notification methods to the citizens of Fire District #37 by implementing a reverse 911 system.				
Yes	Short Term	Yes	City of Kent and Kent Fire Department RFA now utilize Code Red emergency notification system	Ongoing
South King Fire & Rescue Annex				
Educate the public on the risks they face from all hazards and educate them on what they can do to mitigate the impacts on their homes and families				
			No progress reported.	
Mitigate the non-structural impacts of an earthquake on our fire stations				
			No progress reported.	
Mitigate the structural issues found in a recent seismic survey of our fire stations				
			No progress reported.	

PLANNING AREA CHANGES THAT MAY IMPACT PLAN IMPLEMENTATION

No changes to the planning area have been identified that will impact the implementation of this plan. In fact, since the coverage of this plan has significantly been increased during this update process, the opportunity for partnering and leveraging resources has been significantly enhanced.

RECOMMENDATIONS FOR CHANGES OR ENHANCEMENTS

The content and format of this plan has been significantly revised during the course of this plan update process. A crosswalk of changes to the plan are chronicled in volume 1, chapter 2 of this plan update.

Public review notice: *The contents of this report are considered to be public knowledge and have been prepared for total public disclosure. Copies of the report have been provided to local media outlets. The report is also posted on the King County Regional Hazard Mitigation Plan website. Any questions or comments regarding the contents of this report should be directed to:*

Janice Rahman, Emergency Management Program Manager
3511 NE 2nd St
Renton, WA 98056
(206) 205-4061
Janice.Rahman@Kingcounty.goc

APPENDIX C.
PLANNING PARTNER BULLETINS

APPENDIX C.
PLANNING PARTNER BULLETINS

APPENDIX D. HAZARD MITIGATION QUESTIONNAIRE AND SURVEY RESULTS

APPENDIX D.
HAZARD MITIGATION QUESTIONNAIRE AND SURVEY RESULTS

APPENDIX E. CONCEPTS AND METHODS USED FOR HAZARD MAPPING

APPENDIX E.
CONCEPTS AND METHODS USED FOR HAZARD MAPPING

EARTHQUAKE MAPPING

Active Faults and Folds

Fault and fold data are provided by the Washington State Department of Natural Resources, Division of Geology and Earth Resources. These data contain arcs representing the location of faults and folds with known or suspected Quaternary (<1,600,000 years) activity in the state of Washington. Data were gathered from numerous sources, including the Washington State portion of the U.S. Geological Survey's 2010 *Quaternary Fault and Fold Database of the United States*. This dataset contains multiple interpretations of the same faults or fault systems by different authors, which may be only partially co-located. Differing interpretations are the result of different methods used to detect the faults and the scale of the investigation.

Liquefaction Susceptibility

Liquefaction data are provided by the Washington State Department of Natural Resources, Division of Geology and Earth Resources. Data is based solely on surficial geology published at a scale of 1:100,000.

A liquefaction susceptibility map provides an estimate of the likelihood that soil will liquefy as a result of earthquake shaking. This type of map depicts the relative susceptibility in a range that varies from very low to high. Areas underlain by bedrock or peat are mapped separately as these earth materials are not liquefiable, although peat deposits may be subject to permanent ground deformation caused by earthquake shaking. Liquefaction is a phenomenon in which strong earthquake shaking causes a soil to rapidly lose its strength and behave like quicksand. Liquefaction typically occurs in artificial fills and in areas of loose sandy soils that are saturated with water, such as low-lying coastal areas, lakeshores, and river valleys. When soil strength is lost during liquefaction, the consequences can be catastrophic. Movement of liquefied soils can rupture pipelines, move bridge abutments and road and railway alignments, and pull apart the foundations and walls of buildings.

National Earthquake Hazard Reduction Program Soil Classification

Soil classification data are provided by Washington State Department of Natural Resources, Geology and Earth Resources Division. The dataset identifies site classes for approximately 33,000 polygons derived from the geologic map of Washington. The methodology chosen for developing the site class map required the construction of a database of shear wave velocity measurements. This database was created by compiling shear wave velocity data from published and unpublished sources, and through the collection of a large number of shear wave velocity measurements from seismic refraction surveys conducted for this project. All of these sources of data were then analyzed using the chosen methodologies to produce the statewide site class maps. The polygons were classified with site classes based on criteria described in Palmer et al. 2004.

Probabilistic Peak Ground Acceleration Maps

Probabilistic Peak Ground Acceleration data are generated by Hazus-MH 2.1. In Hazus' probabilistic analysis procedure, the ground shaking demand is characterized by spectral contour maps developed by the United States Geological Survey (USGS) as part of a 2008 update of the National Seismic Hazard

Maps. USGS probabilistic seismic hazard maps are revised about every six years to reflect newly published or thoroughly reviewed earthquake science and to keep pace with regular updates of the building code. Hazus includes maps for eight probabilistic hazard levels: ranging from ground shaking with a 39% probability of being exceeded in 50 years (100-year return period) to the ground shaking with a 2% probability of being exceeded in 50 years (2,500-year return period). Earthquake mapping for this plan used the 100-year and 500-year probabilistic events.

Shake Maps

A shake map is designed as a rapid response tool to portray the extent and variation of ground shaking throughout the affected region immediately following significant earthquakes. Ground motion and intensity maps are derived from peak ground motion amplitudes recorded on seismic sensors (accelerometers), with interpolation based on both estimated amplitudes where data are lacking, and site amplification corrections. Color-coded instrumental intensity maps are derived from empirical relations between peak ground motions and Modified Mercalli intensity. For this plan, shake maps were prepared for three earthquake scenarios:

- An earthquake on the Tacoma Fault with the following characteristics:
  - Magnitude: 7.1
  - Epicenter: N47.41 W122.71
- An earthquake on the South Whidbey Island Fault with the following characteristics:
  - Magnitude: 7.4
  - Epicenter: N48.05 W122.47
- An earthquake on the Seattle Fault with the following characteristics:
  - Magnitude: 7.2
  - Epicenter: N47.52 W122.37

FLOOD MAPPING

Flood hazard areas are mapped as depicted on draft FEMA Digital Flood Insurance Rate Maps.

Repetitive flood loss data was provided by FEMA as of January 31, 2014. Property addresses were geocoded and then mapped at a county-wide scale. Not all of the addresses listed in the repetitive loss report were able to be geo-coded and, thus, these properties are not represented symbolically on the repetitive flood loss map or included in the spatial assessment.

LANDSLIDE MAPPING

The landslide hazard maps show a combination of areas drawn from three sources: Washington Department of Natural Resources, King County and a slope/soils analysis.

Landslide Areas

Washington State landslide area data are provided by the Washington State Department of Natural Resources, Division of Geology and Earth Resources. This dataset contains 1:24,000-scale polygons defining the extend of mapped landslides in the state of Washington. This dataset is compiled chiefly from pre-existing landslide databases created in different divisions of the Washington State Department of Natural Resources to meet a variety of purposes.

King County landslide hazard area data are downloaded from the King County GIS Data Portal. Landslide areas are areas subject to severe landslide risk identified in the Sensitive Areas Ordinance as:

- A. Any area with a combination of:
  - 1. Slopes greater than 15%
  - 2. Impermeable soils (typically silt and clay) frequently interbedded with granular soils (predominantly sand and gravel)
  - 3. Springs or groundwater seepage.
- B. Any area that has shown movement during the Holocene epoch (from 10,000 years ago to present), or that is underlain by mass wastage debris of that epoch.
- C. Any area potentially unstable as a result of rapid stream incision, stream bank erosion or undercutting by wave action.
- D. Any area that shows evidence of, or is at risk from, snow avalanches.
- E. Any area located on an alluvial fan, presently subject to or potentially subject to inundation by debris flows or deposition of stream-transported deposits.

Potential Landslide Areas

Landslide hazard areas mapped for this plan are taken from three sources:

- Washington Department of Natural Resources Landslide Areas—Data defining the extent of mapped landslides in Washington provided by the Washington Department of Natural Resources Division of Geology and Earth Resources. Compiled chiefly from pre-existing databases created by different divisions of the Department of Natural Resources.
- King County Slide Areas—Areas identified as follows in the King County Sensitive Areas Ordinance:
  - Any area with a combination of:
    - □ Slopes greater than 15%
    - □ Impermeable soils frequently interbedded with granular soils
    - □ Springs or groundwater seepage.
  - Any area that has shown movement in the past 10,000 years or that is underlain by mass wastage debris of that timeframe.
  - Any area potentially unstable as a result of rapid stream incision, streambank erosion or undercutting by wave action.
  - Any area that shows evidence of, or is at risk from, snow avalanches.
  - Any area located on an alluvial fan, presently subject to or potentially subject to inundation by debris flows or deposition of stream-transported deposits.
- Slope/Soils Analysis—Areas defined as follows in data provided by King County DNRP:
  - Areas with slope greater than 40%, as determined from a digital elevation model generated from 2002 LiDAR data.
  - Areas with the following soil types as identified in a 2006 surface geology dataset:
    - □ Q_f (alluvial fans, which are formed by the deposition of sediment from floods and debris flows at a point where a steep drainage course discharges onto an area of low gradient)

- □ Q_{ls} (areas of discrete landslides)
- □ Q_{mw} (colluvium and cumulative debris from small indistinct landslides accumulated on and at the base of unstable slopes).

TSUNAMI MAPPING

Tsunami inundation area data are provided by the Washington State Department of Natural Resources, Division of Geology and Earth Resources. Tsunami inundation is based on a computer model of waves generated by the Seattle Fault (Titov et al., 1997). The model used is the finite difference model of Titov and Synolakis (1998), also known as the Method of Splitting Tsunami (MOST) model (Titov and González, 1997). It uses a grid of topographic and bathymetric elevations and calculates a wave elevation and velocity at each grid point at specified time intervals to simulate the generation, propagation and inundation of tsunamis in the Elliot Bay area. In this MOST model study, the tsunami is generated by a Seattle Fault deformation model that simulates the A.D. 900-930 event as a credible worst-case scenario of magnitude 7.3. Tsunami hazard map of the Elliott Bay area, Seattle, Washington: Modeled tsunami inundation from a Seattle Fault earthquake, by Walsh et al. 2003.

WEATHER MAPPING

Wind Power Class at 50-Meter Height

Annual average wind resource potential data are provided by the National Renewable Energy Laboratory. Wind power class is an indicator of likely resource strength, with a higher wind power class representing higher wind resource levels. The classification information is for utility-scale applications at a 50 meter height.

Annual Average Precipitation (inches) 1981-2010

Precipitation data are provided by Natural Resources Conservations Service National Water and Climatic Center's PRISM project. PRISM is a hybrid statistical-geographic approach to mapping climate. This approach uses point measurements of climate data and a digital elevation model to generate estimates of annual, monthly and event-based climatic elements. These estimates are derived for a horizontal grid from which contour lines are generated.

Annual Average Maximum Temperature (F) 1981-2010

Temperature data are provided by National Water and Climatic Center's PRISM project. PRISM is a hybrid statistical-geographic approach to mapping climate. This approach uses point measurements of climate data and a digital elevation model to generate estimates of annual, monthly and event-based climatic elements. These estimates are derived for a horizontal grid from which contour lines are generated.

Annual Average Minimum Temperature (F) 1981-2010

Temperature data are provided by National Water and Climatic Center's PRISM project. PRISM is a hybrid statistical-geographic approach to mapping climate. This approach uses point measurements of climate data and a digital elevation model to generate estimates of annual, monthly and event-based climatic elements. These estimates are derived for a horizontal grid from which contour lines are generated.

VOLCANO MAPPING

Lahar hazards data are provided by the Washington State Department of Natural Resources, Division of Geology and Earth Resources. These data were produced as part of a project to estimate the potential economic losses from future eruptions of Mount Rainier. The Puyallup Valley was chosen as the focus for the project because it is the valley most susceptible to lahars caused by flank collapse and has the most population and property at risk (Cakir and Walsh, 2012). The following conditions were analyzed:

- Case 1—Large Lahars (Recurrence Interval 500–1000 Years) Shows areas that could be affected by cohesive lahars that originate as enormous avalanches of weak, chemically altered rock from the volcano. Case 1 lahars can occur with or without eruptive activity. The time interval between Case 1 lahars on Mount Rainier is about 500 to 1,000 years.
- Case 2—Moderate Lahars (Recurrence Interval 100–500 Years) Shows areas that could be affected by relatively large non-cohesive lahars, which are commonly caused by the melting of snow and glacier ice by hot rock fragments during an eruption, but they can also have a non-eruptive origin. The time interval between Case 2 lahars from Mount Rainier is near the lower end of the 100- to 500-year range, making these flows analogous to the so-called 100-year flood commonly considered in engineering practice.
- Post-Lahar Sedimentation—Shows areas subject to post-lahar erosion and sedimentation and the ongoing potential for flooding.

FIRE MAPPING

LANDFIRE Fire Regime Groups

The Historical Fire Regime Groups data layer from LANDFIRE categorizes simulated mean fire return intervals and fire severities into five fire regimes defined in the *Interagency Fire Regime Condition Class Guidebook* (Hann et al. 2004). The classes are defined as follows:

- Fire Regime I: 0 to 35 year frequency, low to mixed severity
- Fire Regime II: 0 to 35 year frequency, replacement severity
- Fire Regime III: 35 to 200 year frequency, low to mixed severity
- Fire Regime IV: 35 to 200 year frequency, replacement severity
- Fire Regime V: 200+ year frequency, any severity

The definitions of severity used in these categories refer to the amount of impact on the upper canopy layer of the affected area:

- Low severity—6 to 25 percent of the upper canopy layer is killed by the fire
- Mixed severity—26 to 75 percent of the upper canopy layer is killed by the fire
- Replacement severity—more than 75 percent of the upper canopy layer is killed by the fire

2008 LANDFIRE Fire Behavior Fuel Model

Fuel class data are provided by the USGS Wildland Fire Science, Earth Resources Observation and Science Center. The LANDFIRE fuel data describe the composition and characteristics of both surface fuel and canopy fuel. Thirteen typical surface fuel arrangements or “collections of fuel properties” (Anderson, 1982) were described to serve as input for Rothermel’s mathematical surface fire behavior and spread model (Rothermel, 1972). These fire behavior fuel models represent distinct distributions of fuel loadings found among surface fuel components (live and dead), size classes and fuel types. The fuel

models are described by the most common fire carrying fuel type (grass, brush, timber litter or slash), loading and surface area-to-volume ratio by size class and component, fuel bed depth and moisture of extinction.

- FBFM1: Surface fires that burn fine herbaceous fuels, cured and curing fuels, little shrub or timber present, primarily grasslands and savanna.
- FBFM2: Burns fine, herbaceous fuels, stand is curing or dead, may produce fire brands on oak or pine stands.
- FBFM3: Most intense fire of grass group, spreads quickly with wind, one third of stand dead or cured, stands average 3 feet tall.
- FBFM5: Low intensity fires, young, green shrubs with little dead material, fuels consist of litter from understory.
- FBFM6: Broad range of shrubs, fire requires moderate winds to maintain flame at shrub height, or will drop to the ground with low winds.
- FBFM8: Slow, ground burning fires, closed canopy stands with short needle conifers or hardwoods, litter consist mainly of needles and leaves, with little undergrowth, occasional flares with concentrated fuels.
- FBFM9: Longer flames, quicker surface fires, closed canopy stands of long-needles or hardwoods, rolling leaves in fall can cause spotting, dead-down material can cause occasional crowning.
- FBFM10: Surface and ground fire more intense, dead-down fuels more abundant, frequent crowning and spotting causing fire control to be more difficult.
- FBFM11: Fairly active fire, fuels consist of slash and herbaceous materials, slash originates from light partial cuts or thinning projects, fire is limited by spacing of fuel load and shade from overstory.

Wildland Urban Interface Communities at Risk

Wildland Urban Interface Areas are shown as defined by the Washington State Department of Natural Resources. Published in 2004, this dataset is based on data from the current National Fire Protection Association (NFPA 299) risk assessment, and includes one or several communities with similar wildfire risks.

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APPENDIX F. PLAN ADOPTION RESOLUTIONS FROM PLANNING PARTNERS

APPENDIX F.
PLAN ADOPTION RESOLUTIONS FROM PLANNING PARTNERS

To Be Provided With Final Release

APPENDIX G. PROGRESS REPORT TEMPLATE

APPENDIX G.
PROGRESS REPORT TEMPLATE

King County
Regional Hazard Mitigation Plan Update
Annual Progress Report

Reporting Period: *(Insert reporting period)*

Background: King County and participating cities and special purpose districts in the county developed a hazard mitigation plan to reduce risk from all hazards by identifying resources, information, and strategies for risk reduction. The federal Disaster Mitigation Act of 2000 requires state and local governments to develop hazard mitigation plans as a condition for federal disaster grant assistance. To prepare the plan, the participating partners organized resources, assessed risks from natural hazards within the county, developed planning goals and objectives, reviewed mitigation alternatives, and developed an action plan to address probable impacts from natural hazards. By completing this process, these jurisdictions maintained compliance with the Disaster Mitigation Act, achieving eligibility for mitigation grant funding opportunities afforded under the Robert T. Stafford Act. The plan can be viewed on-line at:

INSERT LINK

Summary Overview of the Plan's Progress: The performance period for the Hazard Mitigation Plan became effective on ____, 2015, with the final approval of the plan by FEMA. The initial performance period for this plan will be 5 years, with an anticipated update to the plan to occur before ______, 2020. As of this reporting period, the performance period for this plan is considered to be __% complete. The Hazard Mitigation Plan has targeted __ hazard mitigation actions to be pursued during the 5-year performance period. As of the reporting period, the following overall progress can be reported:

- __ out of __ initiatives (__%) reported ongoing action toward completion.
- __ out of __ initiatives (__%) were reported as being complete.
- __ out of __ initiatives (___%) reported no action taken.

Purpose: The purpose of this report is to provide an annual update on the implementation of the action plan identified in the King County Regional Hazard Mitigation Plan Update. The objective is to ensure that there is a continuing and responsive planning process that will keep the Hazard Mitigation Plan dynamic and responsive to the needs and capabilities of the partner jurisdictions. This report discusses the following:

- Natural hazard events that have occurred within the last year
- Changes in risk exposure within the planning area (all of King County)
- Mitigation success stories
- Review of the action plan
- Changes in capabilities that could impact plan implementation
- Recommendations for changes/enhancement.

The Hazard Mitigation Plan Steering Committee: The Hazard Mitigation Plan Steering Committee, made up of planning partners and stakeholders within the planning area, reviewed and approved this progress report at its annual meeting held on ______, 201_. It was determined through the plan's development process that a steering committee would remain in service to oversee maintenance of the plan. At a minimum, the Steering Committee will provide technical review and oversight on the development of the annual progress report. It is anticipated that there will be turnover in the membership annually, which will be documented in the progress reports. For this reporting period, the Steering Committee membership is as indicated in Table 1.

TABLE 1.
STEERING COMMITTEE MEMBERS

Name	Title	Jurisdiction/Agency

Natural Hazard Events within the Planning Area: During the reporting period, there were __ natural hazard events in the planning area that had a measurable impact on people or property. A summary of these events is as follows:

- ____________________________
- ____________________________

Changes in Risk Exposure in the Planning Area: *(Insert brief overview of any natural hazard event in the planning area that changed the probability of occurrence or ranking of risk for the hazards addressed in the hazard mitigation plan)*

Mitigation Success Stories: *(Insert brief overview of mitigation accomplishments during the reporting period)*

Review of the Action Plan: Table 2 reviews the action plan, reporting the status of each initiative. Reviewers of this report should refer to the Hazard Mitigation Plan for more detailed descriptions of each initiative and the prioritization process.

Address the following in the "status" column of the following table:

- *Was any element of the initiative carried out during the reporting period?*
- *If no action was completed, why?*
- *Is the timeline for implementation for the initiative still appropriate?*
- *If the initiative was completed, does it need to be changed or removed from the action plan?*

TABLE 2.
ACTION PLAN MATRIX

Action Taken? (Yes or No)	Time Line	Priority	Status	Status (X, O,✓)
Initiative #__—______________________[description]				
Initiative #__—______________________[description]				
Initiative #__—______________________[description]				
Initiative #__—______________________[description]				
Initiative #__—______________________[description]				
Initiative #__—______________________[description]				
Initiative #__—______________________[description]				
Initiative #__—______________________[description]				
Initiative #__—______________________[description]				
Initiative #__—______________________[description]				
Initiative #__—______________________[description]				
Initiative #__—______________________[description]				
Initiative #__—______________________[description]				

TABLE 2.
ACTION PLAN MATRIX

Action Taken? (Yes or No)	Time Line	Priority	Status	Status (X, O,✓)
Initiative #__—______________________[description]				
Initiative #__—______________________[description]				
Initiative #__—______________________[description]				
Initiative #__—______________________[description]				
Initiative #__—______________________[description]				
Initiative #__—______________________[description]				
Initiative #__—______________________[description]				
Initiative #__—______________________[description]				
Initiative #__—______________________[description]				
Initiative #__—______________________[description]				
Initiative #__—______________________[description]				
Initiative #__—______________________[description]				
Initiative #__—______________________[description]				
Initiative #__—______________________[description]				
Initiative #__—______________________[description]				

Completion status legend:
- ✓ = Project Completed
- O = Action ongoing toward completion
- X = No progress at this time

Changes That May Impact Implementation of the Plan: *(Insert brief overview of any significant changes in the planning area that would have a profound impact on the implementation of the plan. Specify any changes in technical, regulatory and financial capabilities identified during the plan's development)*

Recommendations for Changes or Enhancements: Based on the review of this report by the Hazard Mitigation Plan Steering Committee, the following recommendations will be noted for future updates or revisions to the plan:

- ____________________________
- ____________________________
- ____________________________
- ____________________________
- ____________________________
- ____________________________

Public review notice: *The contents of this report are considered to be public knowledge and have been prepared for total public disclosure. Copies of the report have been provided to the governing boards of all planning partners and to local media outlets and the report is posted on the King County Hazard Mitigation Plan website. Any questions or comments regarding the contents of this report should be directed to:*

Insert Contact Info Here